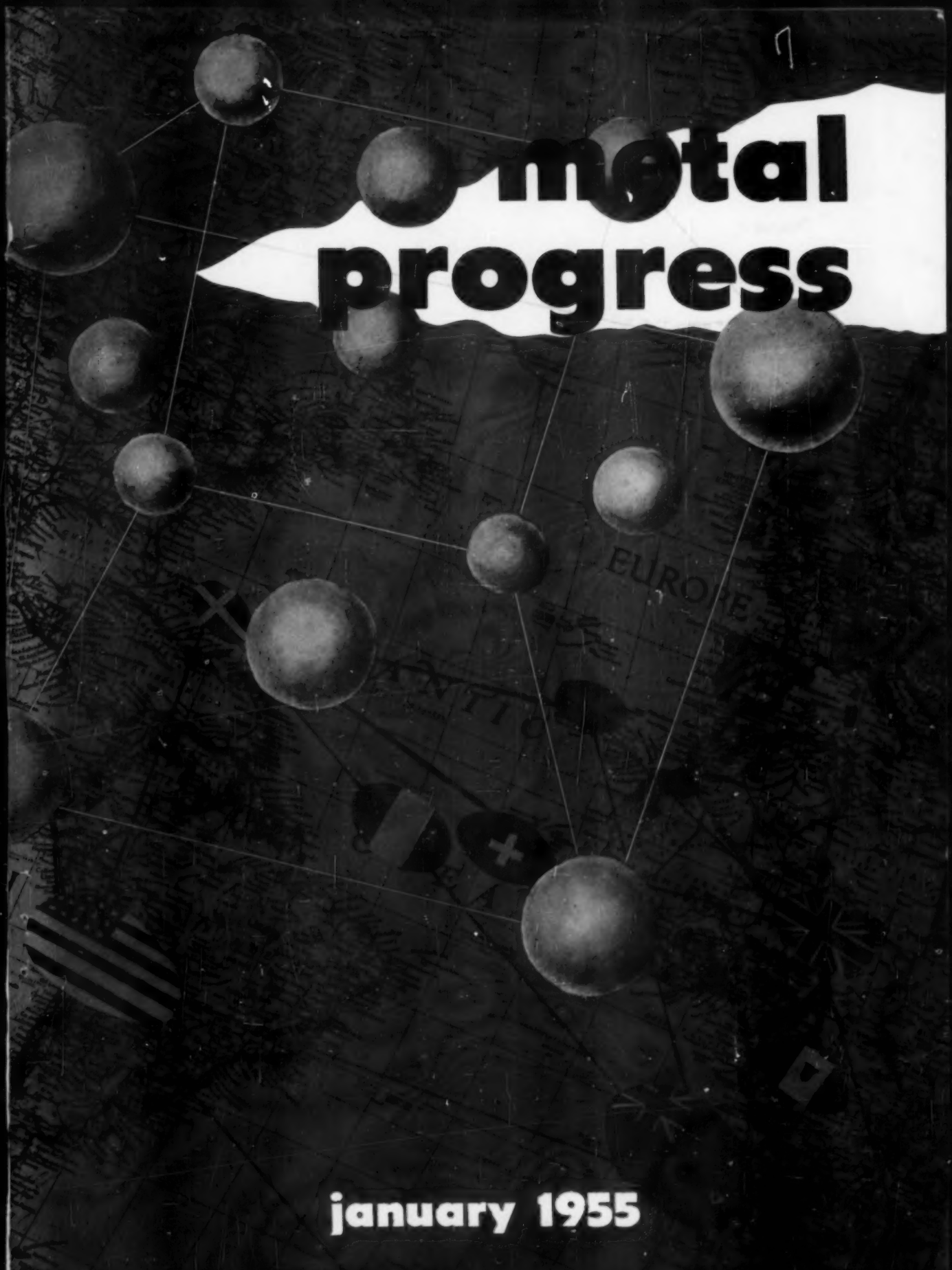
metal
progress
january 1955

mechanized furnace earns 4 ways

AT FREMONT FOUNDRY

You can earn new heat treating profits–like the Fremont Foundry Company in Fremont, O.–using 'Surface' standard furnaces that are equipped with mechanized work handling facilities.

A mechanical pusher, roller rail equipped, double-end oven type furnace, for annealing and stress relieving gray iron castings, is paying off at Fremont Foundry through:

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lower handling costs (only one operator is required for full production);

less plant space (one mechanized furnace replaces two carbottom furnaces; saves one-half the floor space).

In dozens of other installations, mechanized 'Surface' standard furnaces have brought new precision and economy to heat treating.

Send for Literature Group H54-8 and get the story on some of these installations. Your 'Surface' representative will be happy to discuss the standard furnaces and mechanisms to reduce your heat treating costs.

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SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

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Metal Progress

Volume 67, No. 1

January 1955

Cover by Richard Prochaska – *Metal Progress's third international review of progress in metallurgy was the inspiration for this design, which was accorded honorable mention in the annual competition for students at Cleveland School of Art.*

Ernest E. Thum, *Editor*
Marjorie R. Hyslop, *Managing Editor*
John Parina, Jr., *Associate Editor*
Floyd E. Craig, *Art Director*

International Review of Metallurgy

Pig Iron Made From Low-Grade Fine Ore and Noncoking Coal 81

A complete pilot plant for making 40 tons pig iron per day from low-grade granulated ore and noncoking fuel has produced about 8000 short tons of marketable iron in three campaigns. Factors involved are blast enrichment and velocity, charging methods, and amount of fines which can be tolerated in semicommercial operation.

The Copper Industry in Australia, by A. L. Simmons 87

The dilemma of finding more ore reserves for a metal which is suddenly needed in plenty now confronts the Australian copper industry. Production from new workings posed a problem because of the industry's inadequate refining capacity; today the problem concerns the rapidly dwindling 12-year supply of domestic ores. Fabricating capacity, comprised of a number of young and technologically modern companies, will soon be adequate to meet forseeable needs.

The British Non-Ferrous Metals Research Association, by B. Fullman and E. C. Mantle 93

Typical of some 40 British research associations supported by industry with some government assistance is the Non-Ferrous Association with more than 600 member firms. In addition to the principal job of conducting fundamental and applied research, it provides a consulting service for specific problems and an information service.

Contemporary Metal Processing Techniques in Russia, by N. H. Polakowski 98

The only knowledge we have of Russian technology is that which Russia wants us to have. In spite of this severe censorship and regulation of the technical reports and periodicals, enough information leaks through the Iron Curtain to give a few clues to the progress being made in a number of its divisions in metalworking.

Some Recent Work in Physical Metallurgy in Sweden, by Erik Rudberg 104

Incompleted reactions in solid alloys – meta-stability – are under intense study, including bainitic hardening of alloy steels, martensitic hardening of 18-8 stainless, and earliest stages of precipitation hardening in nonferrous alloys.

Residual Stresses–How Dangerous Are They?, by Walter Soete 108

In sound structures residual stresses help propagate brittle fracture at low temperature, affect the yield point, and increase corrosion rates. In structures or machine parts containing minor physical discontinuities, residual stresses may induce brittle fracture at low temperature.

A German View of Brittle Welded Structures, by Edouard Houdremont 114

Tentative German standards specify steels for welded structures by impact strength at definite temperature. The author reviews the causes of brittleness in steels and describes the commercial means of manufacturing tough metal. He believes annealing of weldments – even local annealing of joints – will insure safe performance of a well-designed and honestly fabricated structure.

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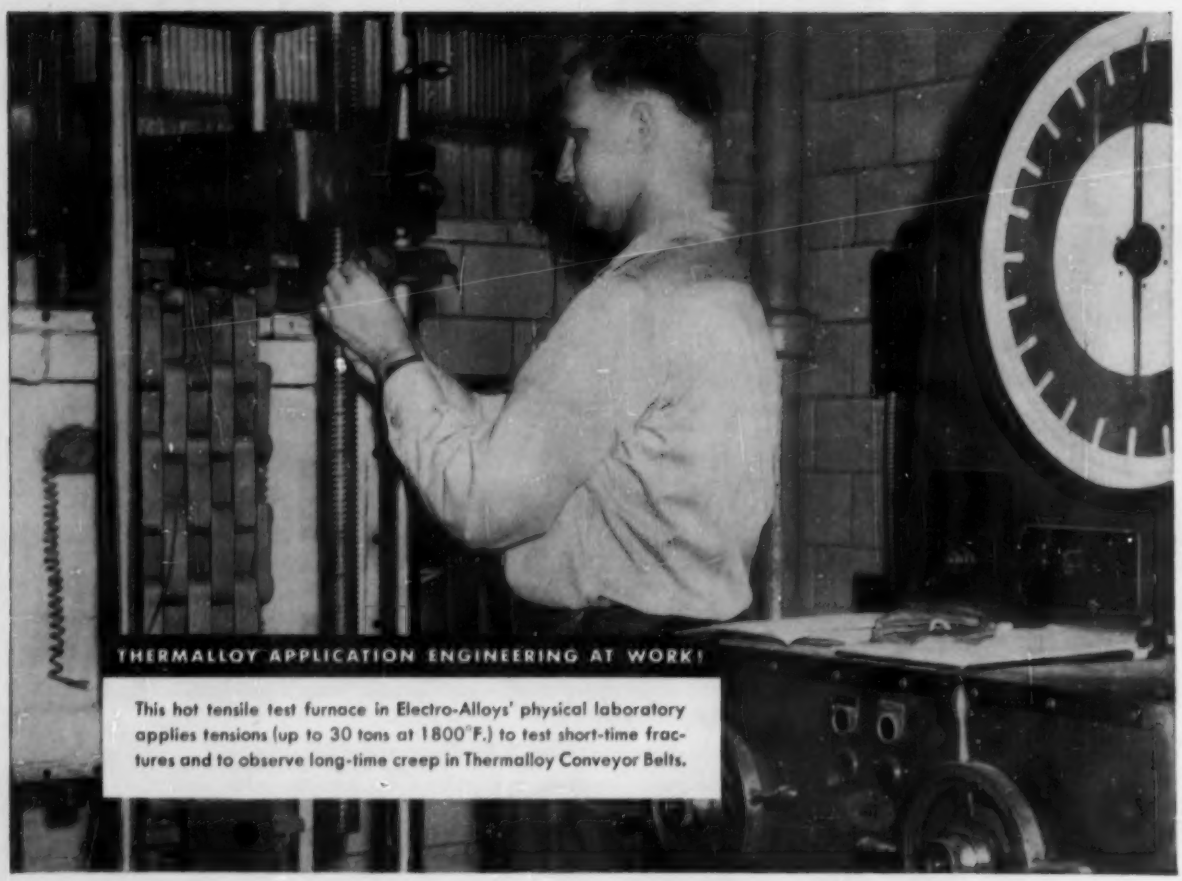
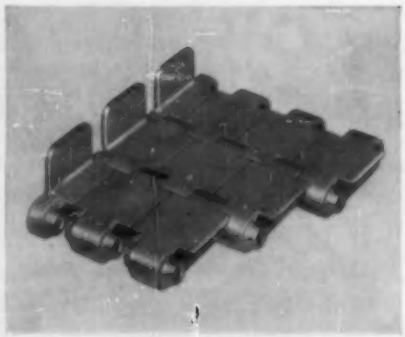

THERMALLOY APPLICATION ENGINEERING AT WORK!
This hot tensile test furnace in Electro-Alloys' physical laboratory applies tensions (up to 30 tons at 1800°F.) to test short-time fractures and to observe long-time creep in Thermalloy Conveyor Belts.

A miniature furnace to test theories!

Service life of a heat-treating furnace conveyor belt may be affected by so many variables, i.e. uneven loading, misalignment, temperature differentials, etc., that proper design, highest quality and the right material are of utmost importance.

At Electro-Alloys, a staff of engineers and metallurgists are constantly studying these factors in the physical testing laboratory shown above. A hot tensile test furnace is continually in use subjecting Thermalloy* conveyor belts to various combinations of loading and temperature. In this way, design theories developed by our engineers are tested and highest possible quality standards are maintained to insure production of furnace conveyor belts that will be the ultimate in trouble-free operation.

Electro-Alloys also applies engineering and metallurgical know-how in the production of heat-resistant Thermalloy castings for other furnace parts such as sprockets, idlers, skid rails or rollers, crossbeams, wall boxes and radiant tube assemblies. For complete information, call our nearest representative or write for Thermalloy Conveyor Belt Bulletin T-241, Electro-Alloys Division, 6002 Taylor St., Elyria, Ohio.



To meet extra-severe operating conditions, a Thermalloy Heavy-Duty Conveyor Belt was developed. This partially assembled belt shows the short integral cast pins that eliminate "crank-shafting."

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION
Elyria, Ohio

*Reg. U. S. Pat. Off.

Advances in Welding in Britain, by E. Bishop 121

The adoption of wartime gains in welding is everywhere evident in Britain. Much interest has been stirred by new concepts in the design of welded structures and the improvement of weldability of high-tensile steels. Among other advances are electrodes that give crack-free deposits, a stitch welder having double the usual welding speed, and the use of twin-cored electrodes to speed manual arc welding.

French Steelmaking Progress in 1954, by G. Husson 127

Optical pyrometers are being attached to converters and the blast (air plus oxygen and steam) regulated so melt is cool until just before the end of the blow. Openhearth research in France is centered on the control of sulphur from high-sulphur fuel oil.

Successful Manufacture and Use of All-Austenitic Welding Electrodes, by Egon Kauhausen and H. A. Vogels 129

Evidence is presented for the belief that cracks of all kinds, however named, in austenitic welds are due to grain-boundary inclusions. Crack-free welds, heavy and light, all austenitic, are in long, severe service. Electrodes are made of clean 16-13 Cr-Ni-Cb steel, under special electric practice. Deoxidizers may sometimes need to be added to the basic lime-fluorspar coatings. Design and construction should also minimize residual stresses.

Origin of the Modern Air-Cooled Cylinder, by S. D. Heron 137

The idea of using aluminum instead of cast iron for the cylinders of air-cooled engines was an important milestone in aircraft development. It apparently originated with an Englishman who was inspired by an unknown Italian; their pioneering work is herewith belatedly acknowledged.

A Turbine-Blade Alloy Castable and Low in Cobalt and Columbium, by W. Siegfried and F. Eisermann 141

An outline of systematic work to discover a "superalloy" capable of investment casting (mass production) and economical in scarce alloying metals. Work also was done which indicates that cast turbine blades are no more susceptible to thermal shock than the forged bladess successfully used in gas turbines.

Improvement of Case Hardened Parts by Controlling Internal Stresses, by Jacques Pomey 147

Proper compressive stresses at and near the surface which raise the endurance limit by 40% can be put into a machine part by carbo-nitriding followed by heat treatments which produce either a bainitic core, a pearlitic core, or a slightly spheroidized core, yet retain a surface approaching 1000 Vickers hard.

New Heat Treating Equipment in Great Britain, by Tom Bishop 154

Annealing of aluminum foil without crinkling, heat treating clad aluminum in salt baths without staining, continuous flash annealing are a few of the nonferrous developments cited; on the ferrous side, the author describes a "drip-feed" liquid for generating a carburizing atmosphere and a scale-free heating method not yet in use in this country.

Atomic Age

A Nuclear Journey Through Europe, by Alvin M. Weinberg 126

A visitor from a U. S. atomic energy project reports on the status of nuclear power utilization abroad.

Data Sheet

Hardenability Bands for Standard H-Steels, 1330-H to 3316-H 128-B

First of a series of eight sheets translating into simplified chart form the hardenability curves and data issued by the American Iron and Steel Institute in February 1954.

Digests of Important Articles

Brittleness in Aluminum Alloys 178
A Method of Controlling Quenching in Baths 182
Fusion Welding of Titanium 194
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As I was saying...

A HAPPY NEW YEAR to you all, no matter where you are – in the deep South, the far North, the extreme East, or the Golden West; this happy phrase is sincerely meant for yours and you. I hope it will be the best year you have ever had, with happiness and success being with you always and crowning your every effort with victory.

Fifty-five should be another great year for your Society, which closed one of its most successful years a couple of months ago. The reports of the past two months are harbingers, I think, of the general prosperity that will surround all activities, whether education or business.

Fifty-five is also going to be a busy year for your A.S.M., beginning with the Western Metal Congress and Exposition in Los Angeles, March 28 to April 1; then the pilgrimage of some 300 Mr. and Mrs. ASMers to the Joint Meeting of Metallurgical Societies in Europe, June 1 to 19, with sessions in England, Germany, Belgium and France, with post-conference invitations for metallurgical meetings in Austria, Switzerland, Italy and Spain; and then again back to the U.S.A. for the 37th annual National Metal Congress and Exposition in Philadelphia, October 17 to 21 (back on A.S.M.'s regular date schedule).

If going to meetings were all the ASMers had to do they would be very busy – but that's not all by a long shot. Big plans for the A.S.M. of Tomorrow have been born and are receiving the nurturing care these activities so well deserve.

I trust all of you have read that portion of the Secretary's report picturing the A.S.M. of Tomorrow, presented at the A.S.M. annual meeting. It was published in full in the December issue of *Metal Progress*, p. 80. I had hinted several times in this column that this big plan was on its way – a sort of teaser campaign to get you to be sure to read it when it appeared.

I was more than pleased with the splendid reception given the presentation at the annual meeting and the many fine words of approval and pledges of assistance to carry out the planned progress of A.S.M.'s activities. And ever since the meeting, letters and words of encouragement arrive in every mail. The plans seem to have struck a responsive chord, and I am happy that the New Year can be a forward-looking one, filled with great enthusiasm and high spirits, using the boundless energy the A.S.M. possesses to work with confidence and pleasurable anticipation to place the A.S.M. on the high plane of usefulness and service to the great metals industry of which it is capable.

So Happy New Year!

Cordially,

W. H. EISENMAN, *Secretary*
AMERICAN SOCIETY FOR METALS

Bill

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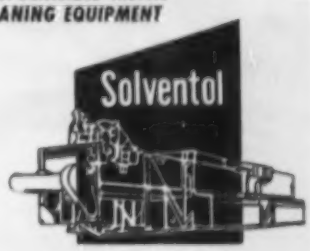

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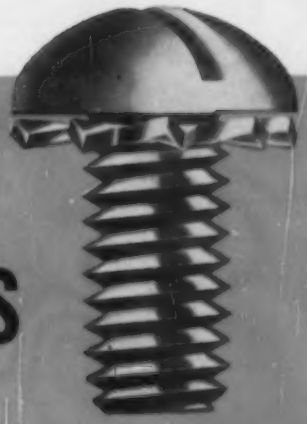
the problem
the answer
Mr. Emerich Bechtold, General Foreman of the Heat Treating Department, and a Gulf Sales Engineer examine the Sems as they emerge from a bath of Gulf Super-Quench.

uniform hardening of SEMS



Gulf Super-Quench

The Shakeproof Division of the Illinois Tool Works had a quenching problem with "Sems" — the well-known screw and lockwasher combination.

Sems are assembled — the lockwasher fitted on the screw—then heat treated. Attaining uniform hardness with conventional quenching oils was difficult, however, because of the difference in size of the heavier screw sections and the normal variations of the steel. The change to Gulf Super-Quench resulted in more uniform hardening, even in the heavier sections, without any cracking of the lockwashers.

Just another example of Gulf Super-Quench's ability to get faster quenching without cracking and distortion, maintain uniform hardness, and cut rejects on many different types of steel parts.

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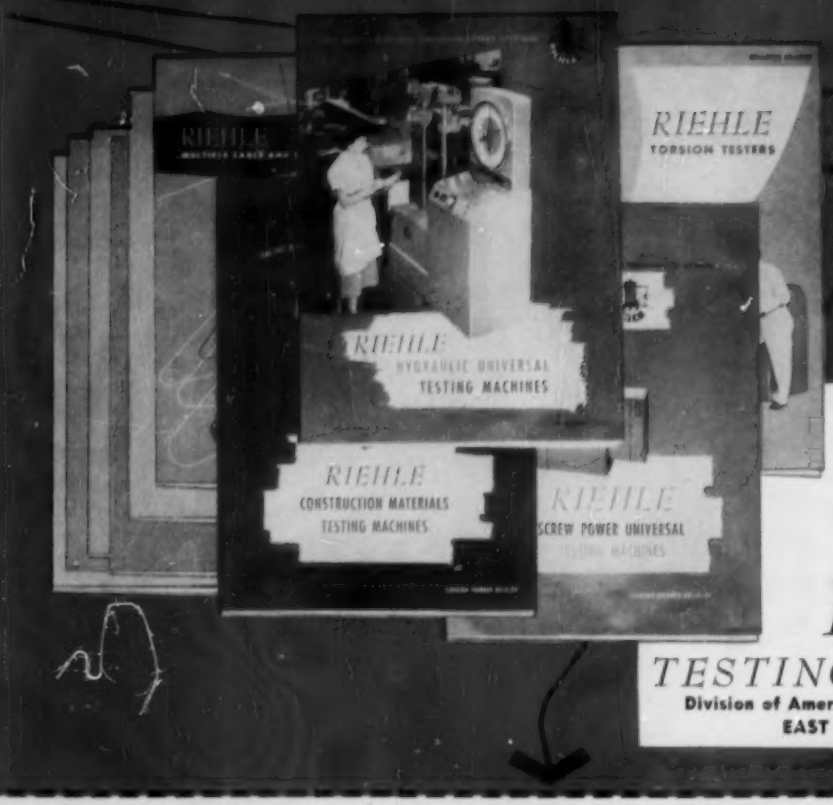

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engineering digest OF NEW PRODUCTS

Gas-Fired Furnace

Leeds & Northrup has announced the extension of its furnace line to include a gas-fired model, made in eight sizes, with work spaces from 15 x 18 in. to 25 x 48 in. The furnaces are vertical, batch-type units, identical with other Homocarb furnaces except for method of firing. The burners are tangential to the combustion chamber, number of burners depending on furnace size. Burners are luminous-flame type, and the use of these burners, with regulation by duration-adjusting type temperature control, produces a long flame which wraps around the furnace retort. The retort thus becomes a single radiant tube, supplying a uniform wall of heat around the work chamber. Continuous, automatic regulation of the carbon content of the furnace atmosphere is provided.

For further information circle No. 1 on literature request card, p. 34-B.

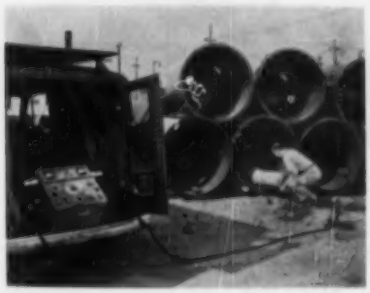
Arc-Melted Metals

The Metallurgical Products Co. has announced that it is making available uncontaminated arc-melted ingots to specification. The nominal composition of all alloys is controlled by an analytical balance giving accuracy to 10^{-4} grams. Melting is carried out under partial or positive pressures of helium, argon or nitrogen. All arc-melting is done on a water-cooled copper hearth. The nature of the process is such that the material during melting is retained within its own thin solid surface, due to special properties of the water-cooled copper used as a hearth. Homogeneity of the melt is assured by the stirring action of the arc and by melting each ingot twice, turning it over between melts. The technique has been used for titanium, zirconium, germanium, nickel, vanadium, molybdenum, copper, manganese, aluminum, iron, tungsten and chromium.

For further information circle No. 2 on literature request card, p. 34-B.

Portable X-ray

A new type of portable industrial X-ray unit capable of producing a 360 degree radiation sweep has been announced by the General Electric X-Ray Dept. Many products can be set up in a circle around the head of the machine and all can be X-rayed with a single exposure. The unit can also operate as a conventional type with a limited angle cone of radiation. It can be placed inside a pipe or pressure vessel and used to take inside-out



X-ray views. The machine consists of a tank to house the X-ray tube, linked to control and power source by interconnecting cables. The tube head weighs less than 185 lb., has a diameter of 10½ in. and a length of 42 in. The control, measuring 18 x 18 x 14 in., weighs 145 lb.

For further information circle No. 3 on literature request card, p. 34-B.

Spot Welder

A manual sigma spot-welding process that makes spot, plug and tack welds with the addition of reinforcing filler metal has been announced by Linde Air Products Co. The process makes extra-strong welds in heavier metals, and requires access to only

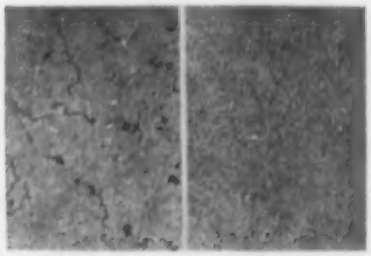
one side of the weld joint. This inert gas shielded welding process feeds consumable wire electrode automatically into the weld area. The filler metal makes a 100% penetration in the lapping metals. The process can be used on carbon and galvanized steel, stainless steel, copper-base alloys.

For further information circle No. 4 on literature request card, p. 34-B.

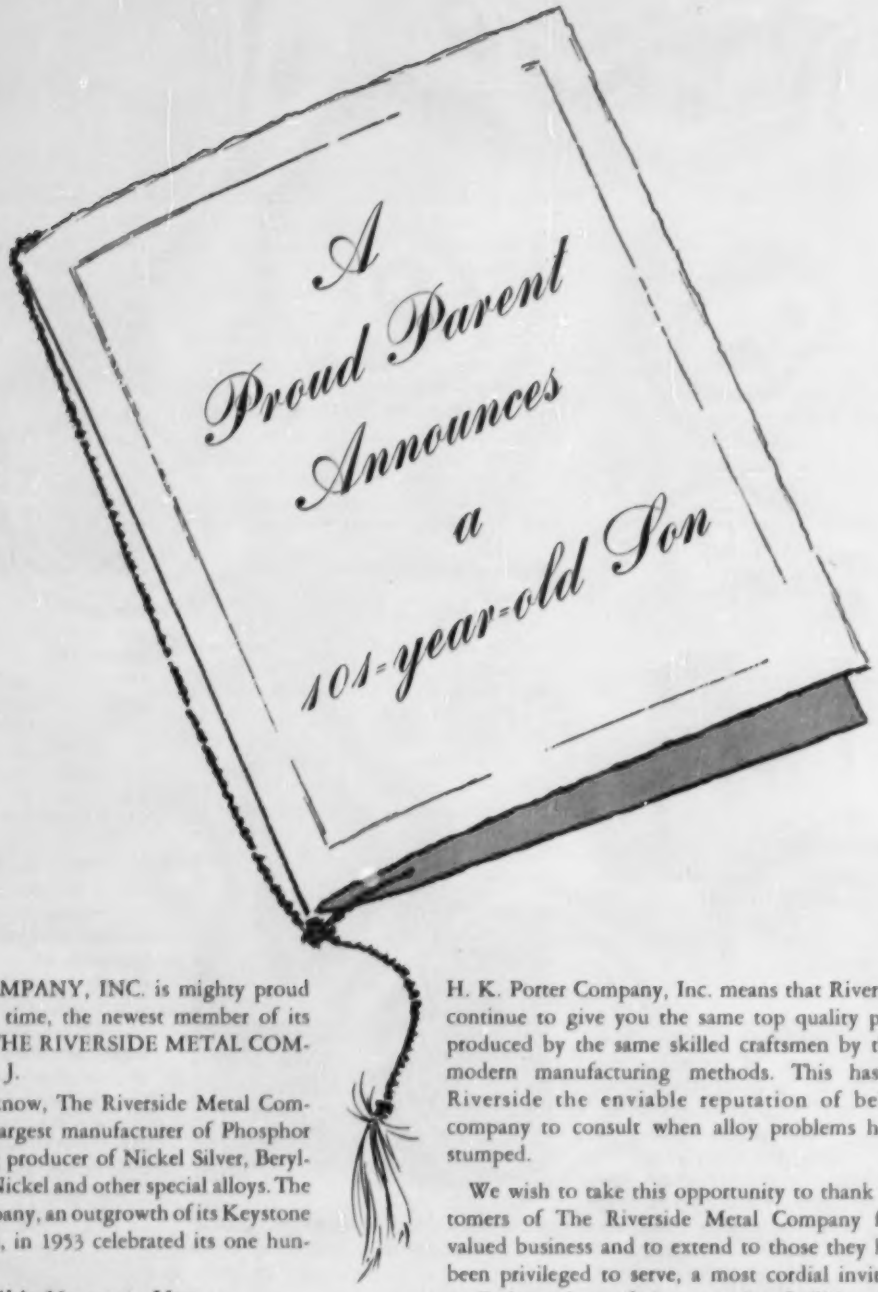
Protecting Magnesium

A new impregnating process which has increased the resistance of magnesium to corrosion from 300 to 400% has been announced by the Nu-Line Plastic Impregnating Co. Samples in the accompanying figure were subjected to continuous salt spray, the untreated sheet at the left for 16 hr. and the impregnated sheet at the right for 98 hr. This new process may further the use of both magnesium sheet and castings in modern industrial design and production.

Magseal is a resin combination which impregnates the metal. After



the metal is removed from the autoclave all parts are rinsed in an alkaline-type cleaning solution. Polymerization is done in a pressure bake oven at 275° F., under 100 psi. This heat under pressure does not allow the im-



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The acquisition of The Riverside Metal Company by H. K. Porter Company, Inc. means that Riverside will continue to give you the same top quality products, produced by the same skilled craftsmen by the most modern manufacturing methods. This has earned Riverside the enviable reputation of being the company to consult when alloy problems have you stumped.

We wish to take this opportunity to thank the customers of The Riverside Metal Company for their valued business and to extend to those they have not been privileged to serve, a most cordial invitation to avail themselves of the extensive facilities they will find at Riverside.

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Costs Cut 60%!

390 pounds of metal body screws per hour are case hardened (0.004" to 0.010") in a single Ajax salt bath furnace no larger than your desk. Bath working dimensions are 36" by 12" by 16". Only 15 to 35 minutes immersion at 1600°F are required — depending on desired case depth. Salt bath carburizing greatly reduced rejects and eliminated a pickling operation.

Tractor drive pinions are selectively carburized in this typical Ajax electric salt bath installation. By immersing only the gear in the bath, carburization is obtained where desired and the unheated portions remain unaffected.

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Send Your sample parts to the Ajax Metallurgical Service Laboratory for processing. No cost or obligation.

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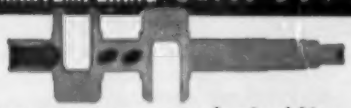

One operator runs a mechanized Ajax line that carburizes and martempers 65 outboard motor crankshafts per hour. Case depth of 0.040" is quickly obtained in a 1760°F bath. Besides an over-all savings of 35%, a copper plating operation and a straightening operation were eliminated. Rejects averaging 4% previously were practically eliminated.

Selectively CARBURIZED AND MARTEMPERED!

Only the teeth and internal spline of this AMS6260 gear are carburized to a 0.035 inch case with a 4½-5 hour immersion. Copper plating of the balance of the piece inhibits carburization. After carburizing and air cooling, gear is reheated and martempered at 500°F for 3½ minutes. Final hardness is Rc 62/63.

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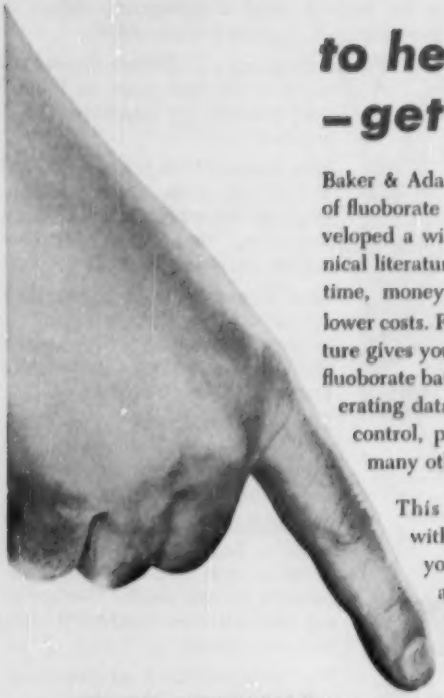

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☐ TB-36431 High Speed Forming of Electrotype Shells
☐ TC-36431 Plating of Baby Shoes
☐ TD-36431 Plating of Plastics
☐ TE-36431 Plating of Rotogravure Cylinders
☐ TF-36431 Manufacture of Sound Records
☐ TG-36431 Plating of Printed Circuits
☐ RA-36431 "Copper Plating From Fluoborate Solutions," reprinted from "The Monthly Review," official organ of the American Electroplaters Society, September, 1946.
☐ RB-36431 "Copper Fluoborate Plating Experiences," reprinted from "The Electroplaters and Stereotypers Magazine," June, 1953.

Ferrous Fluoborate

☐ TA-37641 Iron Plating of Stereotypes
☐ RA-37641 "Iron Plating Curved Stereotypes From a Fluoborate Bath," reprinted from "The Electrotypers & Stereotypers Magazine," July, 1952.

Fluoboric Acid

☐ TA-30691 Applications in Metal Finishing

Indium Fluoborate

☐ TA-37991 Indium Plating From Fluoborate Solutions

Lead Fluoborate

☐ TA-38351 Lead Plating From the Fluoborate Bath
☐ TB-38351 *Lead-Tin Alloy Plating From the Fluoborate Bath
☐ TC-38351 *Lead-Tin Alloy Plating in Electrotyping and Other Applications
☐ RA-38351 *"Metal Coatings Improve Solder Flow on Steel and Brass," reprinted from "Materials & Methods," May, 1949.
☐ RB-38351 *"Solderability of Lead-Tin Alloy Plating," reprinted from "Iron Age," December 8, 1949.

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Nickel Fluoborate

☐ TA-40221 Barrel Plating
☐ TB-40221 Plating Stereotypes
☐ TC-40221 Plating Upon Aluminum
☐ RA-40221 "Barrel Plating with Nickel Fluoborate," reprinted from "Plating," October, 1950.
☐ RB-40221 "High Speed Nickel Plating of Curved Stereotypes," reprinted from "Electrotypers & Stereotypers Bulletin, March, 1950.
☐ RC-40221 "Nickel Plating From Fluoborate Solution," reprinted from "Plating," December, 1950.

Tin Fluoborate

☐ TA-43441 Tin Plating From the Fluoborate Bath
☐ TB-43441 Plating of Electrotype Shells
☐ TC-43441 Electrotinning of Copper Wire.

See Also Articles Marked*.

Name _____ Title _____
Company _____ Address _____
City _____ Zone _____ State _____
MS-1

pregnant to weep, keeping all the resin under the metal's surface. Upon removal from the oven all parts are placed in another alkaline-type stripper solution that removes any remaining impregnant from surfaces.

For further information circle No. 5 on literature request card, p. 34-B.

Polishing Machines

A new series of tandem roll horizontal polishing machines has been announced by Central Machine Works. These machines feature electrohydraulic controls, a hydraulic contour device for automatically following the contours of shaped pieces, and the tandem roll which permits rough cut,

or cut-down, and finishing at only one work set-up. The machines will handle extrusions of all types, sheets, plates, rods, tubing and many odd-shaped items. The work or fixture table is available in any width or length and may be oscillated crosswise at the will of the operator.

For further information circle No. 6 on literature request card, p. 34-B.

Deep Draw Presses

A new line of presses for high-production deep-draw work has been announced by the Steelweld Machinery Div. of Cleveland Crane & Engineering Co. The machines will operate at high speeds during the nonproductive portion of the ram stroke and at a slower, correct drawing speed during the working part of the stroke. This is accomplished through a newly developed linkage that provides quick approach, quick return and slow constant velocity through the drawing range. Press operating speeds can be up to 80% greater in strokes per minute than for an equivalent crank press with the same stroke and yet provide the same drawing speed. Hi-Draw presses are available in single or double-action, one, two, or four-point types. Sizes range up from 160 tons.

For further information circle No. 7 on literature request card, p. 34-B.

Silver Brazing Alloy

A silver brazing alloy developed to overcome crevice corrosion problems in brazing the 400 series of chromium stainless steels has been announced by Handy & Harman. This new alloy contains 63.0% silver, 28.5% copper, 6.0% tin and 2.5% nickel. It melts at 1325° F. and flows at 1475° F. It does not flatten out at brazing temperature to form thin fillet edges as do most silver brazing alloys, which aids in preventing crevice corrosion. Because of its sluggishness, particular care is required to flow the alloy into the joint.

For further information circle No. 8 on literature request card, p. 34-B.

Temperature Control

A new instrument for automatic control of temperature in electric furnaces, ovens and other industrial heating devices has been announced by Thermo Electric Mfg. Co. A bridge system of balancing a known voltage against an unknown voltage is used

with the difference being fed into a saturable reactor. The unknown voltage is supplied by a heated thermocouple and the known voltage is imposed by setting the control dial at the desired temperature. The output of the reactor controls the firing or cut-off of a Thyratron which in turn opens or closes the power relay.

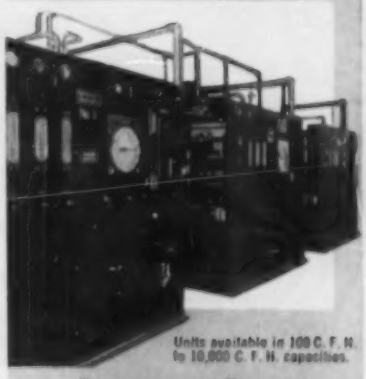
For further information circle No. 9 on literature request card, p. 34-B.

Vacuum Melting

A vacuum melting and casting furnace suitable for moderate-size production of high-purity metals or for

furnace brazing of stainless steel

- Fully Automatic—no operating personnel required.
- High Purity—completely oxygen-free.
- Safe—NO explosion hazard.
- Economical—30% cheaper than dissociated ammonia.



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. . . produces pure nitrogen with a controllable hydrogen content that can be varied to meet changing requirements and maintained at any desired percentage between .25% and 25%. This flexibility permits the use of proper gas for any material or process at lowest cost.

Applications include bright annealing, heat treating and furnace brazing of stainless steel, low and high carbon steels and non-ferrous metals.

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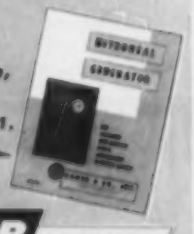

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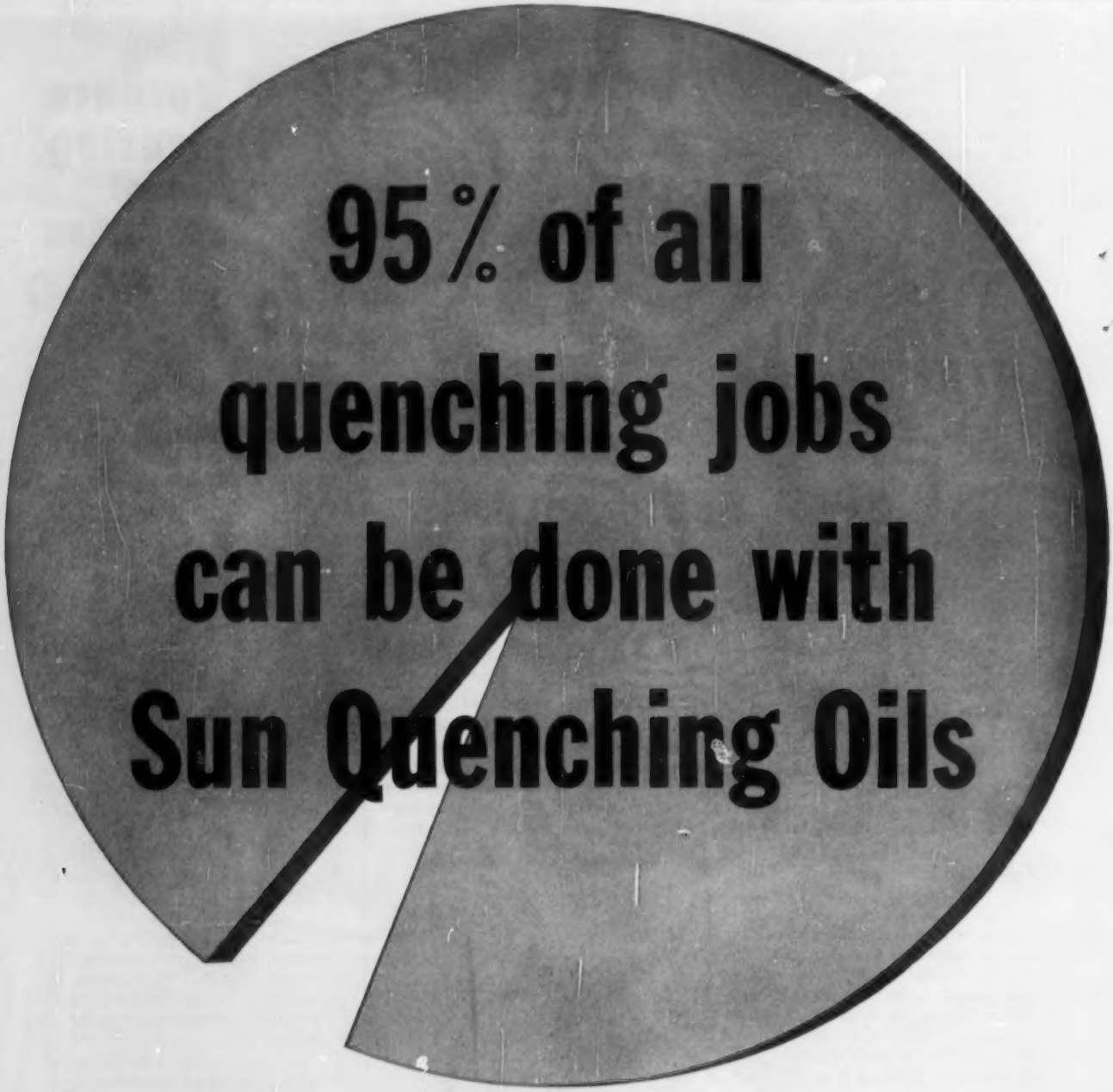

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experimental and pilot-scale work has been announced by F. J. Stokes Machine Co. It has a melting capacity of 50 lb. of steel or other metals. It can be equipped with a tilting crucible and a 2 ft. turntable on which multiple molds can be supported for semi-continuous casting, or for casting by bottom pouring. The chamber for this furnace is a horizontal cylinder 4 ft. in diameter and 4 ft. long.

For further information circle No. 10 on literature request card, p. 34-B.

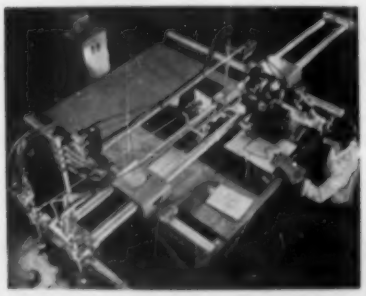
Temperature Control

A new sensitive, self-contained Capacitrol has been announced by Wheelco Instruments Div. of the Barber-Colman Co. This instrument is used in the control of continuous fuel-fired processes which require a true proportional relationship between fuel input and a continuously measured temperature. It incorporates a modified bridge-type control circuit. An integral polarized relay, a component of the feed back circuit, is used as the actuator for a fuel valve power unit. Unbalance causes the valve operator to move in a direction to restore the temperature toward the set point and again bring the electrical bridge into balance. Both the temperature measuring system and control chassis are of plug-in design.

For further information circle No. 11 on literature request card, p. 34-B.

Cutting Machine

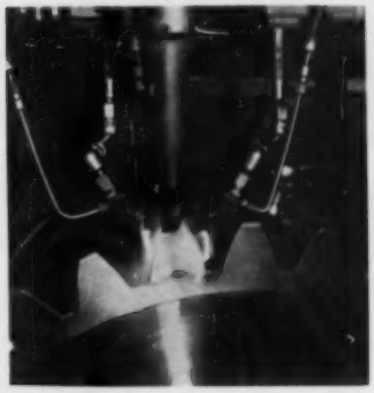
Air Reduction has announced a new oxyacetylene shape cutting machine which operates with four torches. The torches may be arranged in a wide variety of positions. The cutting range of the machine when equipped with one tracing table is 48 in. wide by 51 in. long. Four 48-in. circles can be cut simultaneously with two torches at each end of the machine. Cutting length can be extended indefinitely by the addition of extra tracing tables. Electronic, magnetic and manual tracers can be used and are interchangeable on the machine.



For further information circle No. 12 on literature request card, p. 34-B.

Surface Hardening of Gear Teeth

A sensitive electronic control is featured on the new and improved models of gear surfacing hardeners, according to the Gleason Works. On these machines oxyacetylene flames traverse each individual tooth separately. A sensitive radiation pyrometer is focused directly on the tooth being heated, and receives radiant energy from the hot metal. An electronic balancing mechanism translates that energy into forces which control the travel of the burners along the tooth. Operation of the machines is entirely automatic. The No. 1 machine accommodates bevel gears up to 24 in. pitch diameter, spur and helical gears up to 30 in. pitch diameter and internal gears up to 24 in. outside diameter. The No. 2 machine takes gears up to 120 in. pitch diameter.



For further information circle No. 13 on literature request card, p. 34-B.

Rust Removal

Oakite Products has announced the development of an alkaline derusting product for precision parts where dimensional change and acid embrittlement must be avoided. It is a heavy-duty, off-white powder that may be used in hot or cold solutions. It may be used with direct current to remove deep-pitted rust, or reverse current to remove heat scale.

For further information circle No. 14 on literature request card, p. 34-B.

Direct Reading Spectrometers

Baird Associates has announced a new research spectrometer, designed for handling a wide range of materials under diverse conditions of sample

Need Impregnation?

You've got an impregnation problem, and you need help . . . Why waste time with hit-and-miss methods — come to the expert, your Metaseal impregnation engineer.

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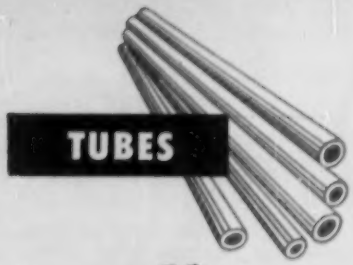

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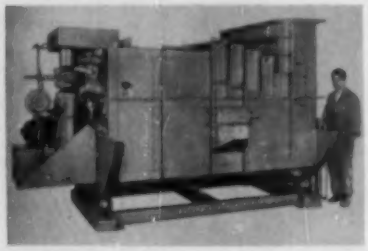
concentration, range, excitation, elements and matrices, and a new model production control direct reader for routine control problems which involve a limited number of elements and ranges. Both instruments feature a newly designed optical mount and redesigned sample compartment and electronic components. The research instrument will offer a wide spectral range on the cassette, rapid interchange of flats and pins, facilities for samples in the form of sheets or solution and a substantially reduced step-up time through improved construction features.

For further information circle No. 15 on literature request card, p. 34-B.

Reverberatory Furnace

A tilt-type reverberatory furnace, with a bath capacity of 6000 lb. of brass, has been announced by Eclipse Fuel Engineering Co. The combustion assembly and controls tilt with the furnace when the metal is being poured. Tilting operation is controlled



by a valve near the pouring spout. Using light oil for fuel, two burners fire into the combination melting and holding chamber. Ingot is charged through the hopper. Only preheated metal reaches the melting zone, and only molten metal reaches the bath.

For further information circle No. 16 on literature request card, p. 34-B.

Zinc Plating

A bright zinc electroplating process has been announced by Frederick B. Stevens, Inc. Developed for automatic manual and semi-automatic barrel plating, the new process produces a bright zinc plate over a wide range of current densities such as are found in barrel plating. The process is composed of water soluble bright zinc salt and liquid zinc brightener. The resulting surface can be bright dipped or given a chromate treatment.

For further information circle No. 17 on literature request card, p. 34-B.

Two-Wire Thermocouple

A new two-wire thermocouple, encased in stainless steel tubing, has been introduced by the Industrial Div. of Minneapolis-Honeywell Regulator

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Small, intricate parts that formerly required costly machining or assembly time can now be produced economically, accurately, and to a high finish, by Precision Investment Casting. Parts with undercuts, cores, and holes, are a "natural" for this precision process.

This modern casting technique offers increased production, lower manufacturing costs, and a greater freedom in the development of new parts.

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When up against a finishing problem, many engineers and designers like to get the opinions of a finishing specialist. They prefer to consult a company that knows many types of finishes.

Because United Chromium has developed plating processes, specialized organic protective coatings, and a wide line of chromate finishes, it can be a real help in suggesting the best type of finish to meet service, appearance and cost requirements.

ELECTRODEPOSITED COATINGS

Unichrome Copper, Nickel and SRHS Chromium comprise the first matched set of plating processes. This means one source, one responsibility for proper operation which in turn means the finest finish of its kind plus smoother running production.

UNIQUE ORGANIC COATINGS

Developed to meet unusual requirements, Unichrome lacquers, synthetics, enamels are now available in a broad range to block corrosion, add long life to the eye appeal of a product.

CONVERSION COATINGS

Chromate treating strengthens corrosion resistance of zinc die castings and plate. It offers an easy, economical way to finish. With Unichrome Dips, high quality also is obtainable—quality measured in durability and appearance.

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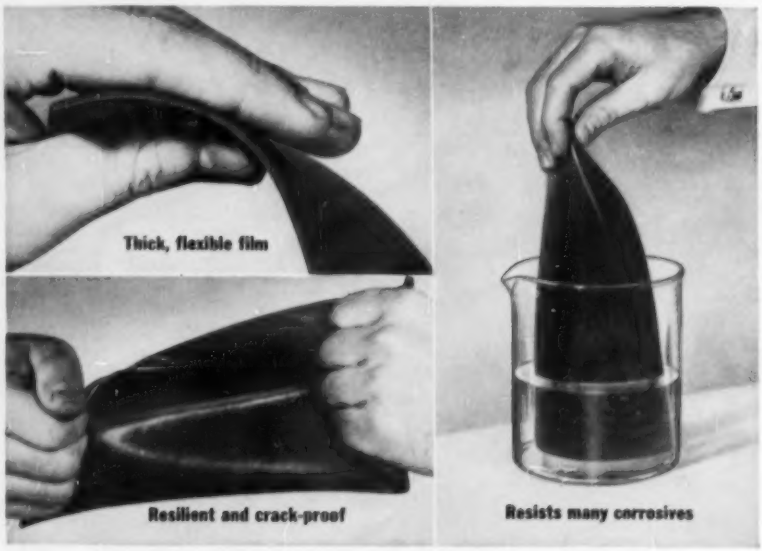
Advantages of Unichrome heavy-duty vinyl compounds now obtainable even with sprayed coatings



PLASTISOL compounds are liquids, which when heat cured, build up vinyl plastic finishes that look and feel like rubber, but there the resemblance ends. Plastisols offer truly remarkable chemical resistance, which is further fortified by the tough, substantial film thickness achieved in one coat.

SEAMLESS, THICK-FILM PROTECTION

Any metal surface that can be uniformly baked can now be strongly protected against severe and corrosive service conditions by Unichrome 4000 Series Plastisol Compounds—or the new Coating 5300. The first practical *sprayable* plastisol, Unichrome Coating 5300 fills the need for a plastisol suitable for application to products too large to be dip-coated.

A 20 mils thick, non-sagging coat can be applied even to cold vertical surfaces in just one application with Coating 5300. That's 5 to 20 times thicker than ordinary coatings. Unichrome Series 4000 Plastisols, which are applied by almost any other conventional method, produce coatings up to 3/16" thick. Plastisols can do jobs for which sheet materials have been used.

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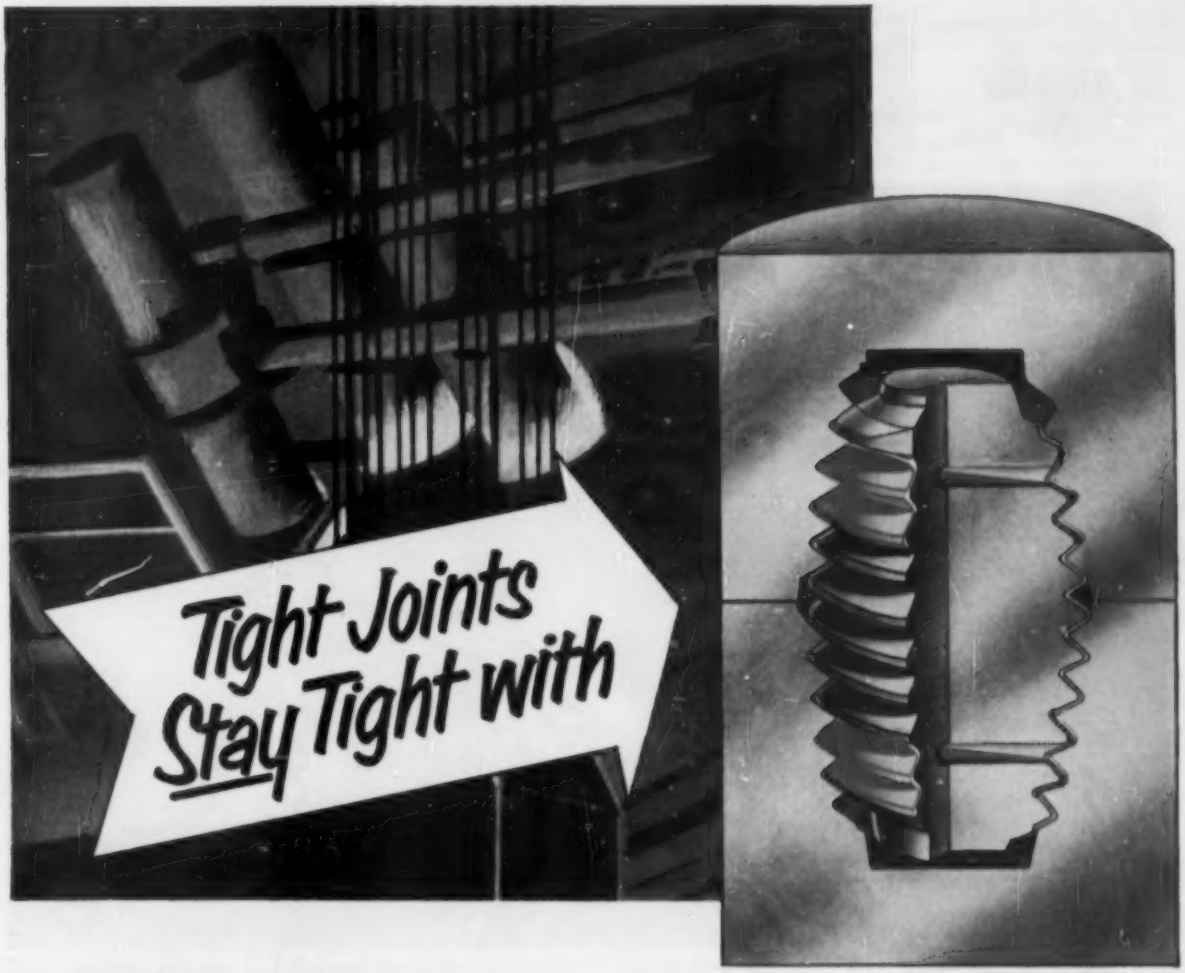
Unichrome Plastisols offer seam-free and pore-free protection against acids, alkalies, water, salt solutions and many other corrosive agents. They bake into an abrasion-resistant resilient coating that doesn't crack, chip or tear. With such protection, ordinary metals can often be used in place of costly alloys.

The chemical resistance, physical toughness, electrical insulating properties, and speed of curing of Unichrome Plastisols combine to offer engineers a new tool for protection and finishing. Send for Bulletin VP-1.



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THE NEW PITCH-RESERVOIR NIPPLE, an exclusive "National" product, is another major contribution by National Carbon Company to more efficient electric furnace operation. You can now be sure that tight joints will stay tight under normal load and service conditions.

"NATIONAL" PITCH-RESERVOIR NIPPLES, designated Type PR-F, are now available for electrode diameters from 14" to 24". Thoroughly proved in service, they are identical in strength, size, shape, tolerances, composition and quality to our standard, tapered, graphite nipples. Talk it over soon with your National Carbon Company electrode representative.

***PATENTS PENDING**
EXCLUSIVE DESIGN

HERE'S HOW IT WORKS:

Reservoirs near each end of the nipple contain pitch. As the electrode column becomes hot in service, the pitch flows from the reservoirs into the threaded sections of the joint and cokes out, cementing and locking the threads of the nipple and sockets together.

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Another Norton ℞ *on the job!*

One of the 1200-pound Ajax induction furnaces used by The Duriron Company, Inc. of Dayton, Ohio. Melts are chiefly stainless steel alloys, tapped at 3200°F or higher. MAGNORITE cement, the Norton ℞ for lining and patching these furnaces, has resulted in substantial savings — not only in the amount and cost of cement, but in time and labor.

The Duriron Company, Inc. doubles heats-per-lining, cuts melting costs, maintains stainless steel quality with MAGNORITE cement*

If re-lining is too frequent a job in your induction furnace operations — if you're using up too much time, cement and money to get maximum heats — we suggest you consider MAGNORITE cement.

Take the experience of The Duriron Company, leading manufacturers of chemical process equipment made of stainless steel and other metals. Before trying MAGNORITE cement, their best previous lining material was giving an average of 68.2 heats per lining. Thorough test runs of MAGNORITE at the Duriron foundry show this Norton refractory material is averaging 140.5 heats per lining. And it is not only lasting twice as long as its best performing competitor, it is more refractory, it has 50% less slag volume on heats, and its freedom from shrinkage eliminates cracking. Another instance of how Norton refractories and refractory materials are *engineered and prescribed* to provide time-and-money-saving ℞'s.

Give MAGNORITE cement a test run

in one of your own furnaces. Note how it withstands temperatures up to 3250°F — how its high-rammed density resists metal penetration, erosion and chemical attack — how its slight expansion when sintered eliminates shrinkage cracks in the crucible lining.

Norton will be glad to specify MAGNORITE cement to your exact requirements, or to help you solve metal-melting problems. Working with MAGNORITE*, ALUNDUM*, CRYSTOLON* and Fused Stabilized Zirconia cements, Norton engineers will find ℞'s you need for efficiency and economy. For details, see your Norton Refractories Engineer, or write to NORTON COMPANY, Refractories Division, 320 New Bond Street, Worcester 6, Mass. *Canadian Representative:* A. P. Green Fire Brick Co., Ltd., Toronto, Ontario.

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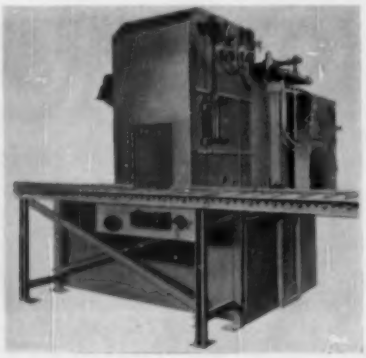
Co. It is available with either an open head assembly or a screw-cover head. The stainless steel protecting tube is expected to double the life of the new thermocouples. Accuracy of the new device is rated at ± 5° F. over a range of 0° to 1000° F. Lengths of the thermocouples range from 6 to 60 in. Lengths of 35 ft. are available on a special basis.

For further information circle No. 18 on literature request card, p. 34-B.

Atmosphere Furnace

Dow Furnace Co. has announced a new furnace which is the smallest of the three batch-type controlled atmosphere furnaces for gas carburizing, carbonitriding, clean hardening and carbon restoration. The furnace has



sealed cycle operation which reduces the time between loads to less than 30 sec. and allows continuous operation, and forced uniform quenching from atmosphere to give full hardness, reduce distortion, eliminate scale. The floor area required is 10 x 12 ft.; heating rate is 400 lb. per hour.

For further information circle No. 19 on literature request card, p. 34-B.

Illuminated Dial Hand Pyrometer

Claud S. Gordon Co. has announced an illuminated dial which is incorporated as an extra in its line of hand

pyrometers. It permits reading the pyrometer in poorly lighted areas without flashlight or auxiliary lighting. Two easily replaced batteries are contained in the handle of the instrument. A push-button switch lights the bulb under the shield.

For further information circle No. 20 on literature request card, p. 34-B.

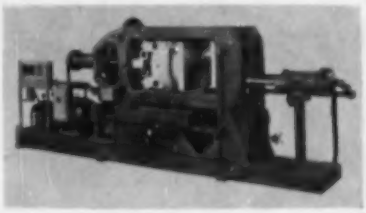
Filter

A filter that incorporates a new filtration principle and gives a large filtering area and volume has been announced by Bart-Messing Corp. The filter can be used with either a corrugated stainless steel and wire mesh filter element which supports a cloth filter bag or standard porous stone elements. The entire filter element is attached to the cover of the tank, and is easily removed for quick inspection, cleaning or replacement. All models have a large stainless steel precoat tank to make precoating a one-step operation.

For further information circle No. 21 on literature request card, p. 34-B.

Die Casting

A 400-ton aluminum die casting machine, designed to cast up to 6¾ lb. of aluminum or proportional weights of magnesium or brass, has been announced by Lester-Phoenix. In the shot assembly, the machine provides 21,000 psi. maximum pressure



on metal. Both shot speed and pressure are adjustable, with an ASME approved nitrogen accumulator giving high speed injection. 400 tons of preload clamping is made possible by the one-piece alloy steel frame with a large beam area.

For further information circle No. 22 on literature request card, p. 34-B.

Clad Steel

Complete fabrication of industrial degreasing equipment with Lectro-Clad steel has been announced by Bart Mfg. Co. Steel is electroplated with deposits of nickel ranging from 0.007 to 0.020 in. thick regardless of the thickness of the steel. Sheets and plates, ranging from 11 gage to 1 in. thick or more, are now being clad with nickel. The electrodeposited nickel is ductile and will withstand any fabricating processes, including welding, which the steel will withstand. Besides degreasing equipment Lectro-Clad is being used for various types of corrosion resistant equipment with thickness of clad being determined by corrosive and erosive factors.

For further information circle No. 23 on literature request card, p. 34-B.

Ultrasonic Generator

A new high-powered multicrystal ultrasonic generator which will make possible the construction of larger and more flexible industrial cleaning equipment has been announced by the General Electric Co. The two units of the generator are the power oscillator, which is enclosed in a separate cab-

inet, and the transducer assembly which contains five quartz vibrating crystals and can be remotely located from the oscillator. The transducers are hermetically sealed so they can be placed directly into a tank of solvent. This allows the generator to be incorporated into a regular vapor-degreasing or hot-dip process.

For further information circle No. 24 on literature request card, p. 34-B.

Atom Models

Arthur S. LaPine & Co. have announced scaled atom models for measuring and studying atomic structures. Thirty different structural units are now available and more are on the way. Connections between the atom models of various elements are made with snap-on fasteners. Small removable spring metal wedges make rigid connections for multiple bonds. Dimensions of the atom models are proportional to the mean of the latest experimental measured values. These models are the largest on the market.

For further information circle No. 25 on literature request card, p. 34-B.

Welding Wire

The Air Reduction Sales Co. has announced the availability of development quantities of an activated electrode, mild steel wire for use in the Aircomatic process. The activation agents change the burn-off rate so that

stable spray-type transfer can be obtained on direct current, straight polarity without the need for oxygen additions to the shielding gas. Also, these wires permit the use of the process with standard alternating current welding power supplies.

For further information circle No. 26 on literature request card, p. 34-B.

Finishing Compounds

Almco Supersheen has announced two new compounds. One is for heavy deburring and grinding operations. It can be used on all metals, but is recommended for ferrous parts. It is a low-foaming compound for use in long runs where heavy foam may develop and deter the grinding function. The other compound was developed for use with all metals, but especially for burnishing of brass, zinc, aluminum and copper.

For further information circle No. 27 on literature request card, p. 34-B.

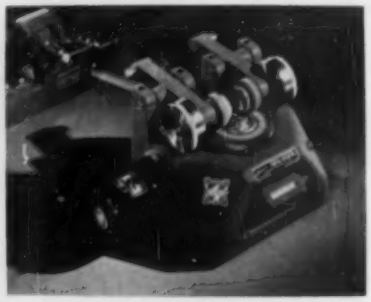
Fatigue Testing

A Sonntag universal fatigue testing machine of 100,000 lb. capacity has been announced by Baldwin-Lima-Hamilton. The new machine was developed to meet a demand for greater capacity in simulated service testing of large machine elements, structural components, and materials in tension, compression, bending, torsion, or combined stresses. It has ten times the capacity of the next largest Sonntag fatigue machine. The table is 6 ft. wide by nearly 12 ft. long. Testing speed is 1500 cycles per minute and maximum movement of the vertically reciprocating, 14 x 14-in platen is ½ in. Controls and contactors are in separate cabinets.

For further information circle No. 28 on literature request card, p. 34-B.

Abrasion Tester

Taber Instrument Corp. has announced a new portable model abrasion resistance tester which performs



practically all the feats of the standard model. Actual wear conditions can be simulated and results read. Minimum technical experience is necessary to conduct scientifically accurate tests.

For further information circle No. 29 on literature request card, p. 34-B.

Ionization Chamber

An ionization chamber on a 50 ft. cable for use with the portable gamma radiation meter has been announced by the Jordan Electronic Mfg. Co. Use of this chamber assembly permits

remote radiation measurement without binoculars, or jury rigged optical systems to prevent personnel from being exposed to dangerous radiation. This chamber is shock isolated in fiber glass, operates over a wide range of −65 to 250° F, and can be used continually

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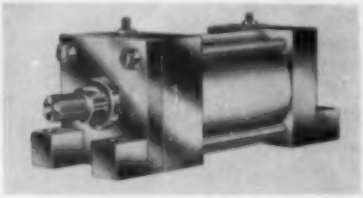
submerged in water. It measures radiation intensities from 0.01 mr. per hr. to over 100,000 r. per hr. and is substantially energy independent from 75 kev. up.

For further information circle No. 30 on literature request card, p. 34-B.

Cylinder Mounting

A new cylinder mounting consisting of sturdy, thick, square mounting lugs that mount flush with standard square heads and caps to provide a space-sav-



ing mounting of great strength and rigidity is now being offered by Miller Fluid Power Co. The mounting model is for side or foot mounting and is available in Miller's complete line of cylinders.

For further information circle No. 31 on literature request card, p. 34-B.

Test Chamber

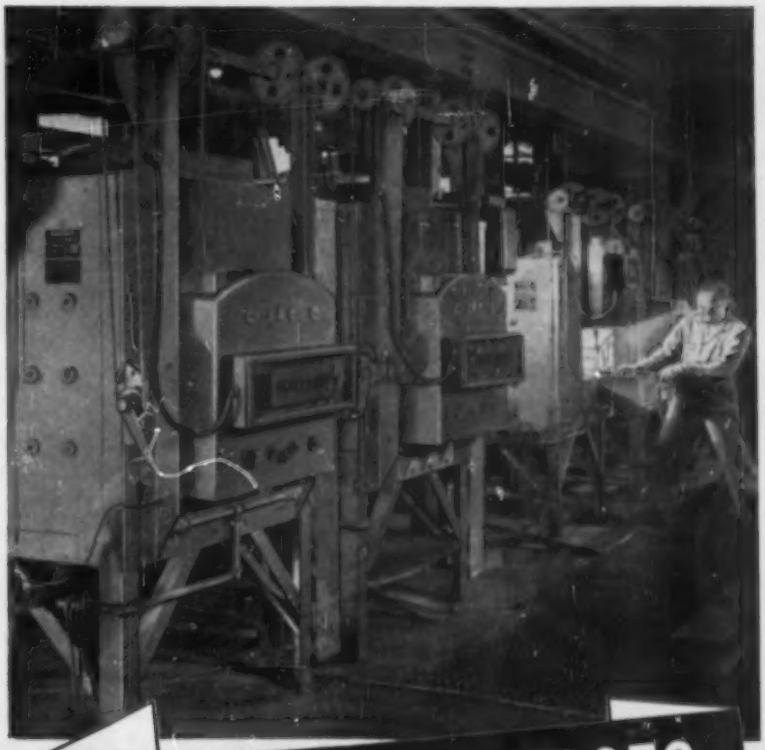
The American Research Corp. has announced an environmental simulation chamber which will provide up to 7½ psi. positive pressure in addition to automatically controlled temperature-altitude-humidity simulation. Temperatures from +185 to —100° F.

can be maintained at altitudes up to 60,000 ft. Other features include automatically controlled relative humidity from 20 to 100%, automatic control of pressure and altitudes and automatic draining of all humidity devices below freezing.

For further information circle No. 32 on literature request card, p. 34-B.

Coatings

Atlas Mineral Products has announced a line of coatings based on Neoprene. This line consists of Neobon, a mixed heavy rubber coating; Neelium, a high solids, high built liquid Neoprene coating; a caulking material and Elprene, a liquid main-



HEVI DUTY FURNACES
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Are Versatile . . . . .
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● These Hevi Duty Box Furnaces at the A. O. Smith Corp. of Milwaukee, Wisconsin are used for hardening production tools that vary in weight from a few ounces to several hundred pounds. Hevi Duty Furnaces provide the uniform temperatures needed for precision heat treating.

Send for bulletins HD-341 and HD-441

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HEAT TREATING FURNACES HEVI-DUTY ELECTRIC EXCLUSIVELY
DRY TYPE TRANSFORMERS — CONSTANT CURRENT REGULATORS
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There's no *"...or equal"* for EASY-FLO and SIL-FOS

EASY-FLO and SIL-FOS are the original low-temperature silver brazing alloys conceived and perfected by Handy & Harman metallurgists.

Years of research went into the development of the alloys and the manufacturing methods and quality controls used in their production. In composition, in physical properties and in unvarying uniformity, EASY-FLO and SIL-FOS alloys stand alone.

It is from these exclusive features that EASY-FLO and SIL-FOS alloys get their remarkably fast brazing action and ability to make high-strength, liquid and gas-tight joints, consistently and at surprisingly low cost. That's why there's no *"or equal"* for EASY-FLO and SIL-FOS alloys when it comes to fast, reliable, economical metal joining.

and there's no *"...or equal"* for these SERVICES

The following technical and practical assistance is available, without cost or obligation, to all users of EASY-FLO and SIL-FOS alloys through Handy & Harman's engineering and research departments, field service staff and nearest distributor.

DEMONSTRATIONS of EASY-FLO and SIL-FOS silver brazing in your own shop.

SURVEYS of your metal joining to determine if and where EASY-FLO or SIL-FOS brazing can benefit you.

DESIGN AID for your engineers to assure best joint design for EASY-FLO or SIL-FOS brazing.

SAMPLE BRAZING of your parts by our technicians to determine the best way to silver braze them.

PRODUCTION AID to help work out the procedure that will give you the output you want at lowest cost.

OPERATOR TRAINING of your key men in our brazing schools, or by a program we set up in your plant.

RESEARCH in our laboratories to work out your special silver alloy brazing problems.

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You can get the real EASY-FLO and SIL-FOS alloys, and their companion low-temperature HANDY FLUX, only from Handy & Harman Authorized Distributors. They're located in principal centers throughout the country. Write for the "Distributor List" and contact the nearest one.

BULLETIN 20 contains the full facts about EASY-FLO and SIL-FOS. It makes clear why these alloys are being used today, in tremendous quantities throughout all industry. It also includes useful information about joint design and fast brazing production methods. Write for a copy.

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tenance coating. These products are available in gray and black and can be applied to metal or concrete. Neobon and Elprene can be applied by brush, roller coater or spray gun.

For further information circle No. 33 on literature request card, p. 34-B.

Induction Heater

A new 25-kw. high-frequency vacuum tube induction heater for heavy duty industrial use has been announced by Allis-Chalmers Mfg. Co. It will convert 60 cycle power into radiofrequency power of approximately 450,000 cycles. The entire cubicle of the unit is pressurized. Air is

drawn into the heater near the top, filtered, blown downward through the oscillator, through a baffle, into the rectifier section, and then exhausted through a grille on the rear panel of the cubicle. Ceramic coils carry cooling water to high potential parts.

For further information circle No. 34 on literature request card, p. 34-B.

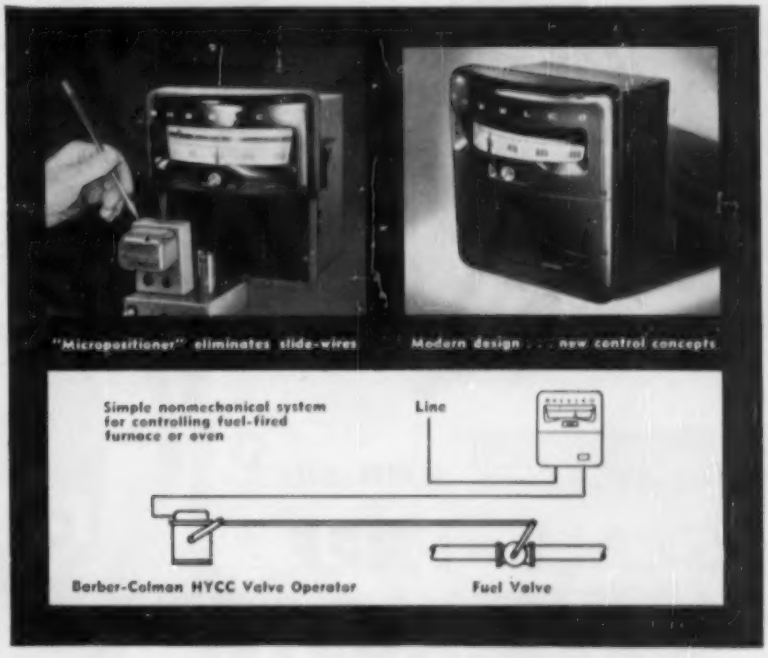
High-Vacuum Furnace

New high-vacuum systems, larger than any now in industrial use, and capable of operating at lower pressures than are achieved by any present production equipment, are being built by the Consolidated Vacuum Corp. Among the units under construction is a high vacuum furnace that will be able to melt and pour 1000-lb. ingots of metal and that will operate continuously without breaking the vacuum. In this furnace, while one charge is being melted and poured in the vacuum chamber, another charge will be introduced through an air lock. Ingots will also be removed through an air lock as soon as they have cooled sufficiently for handling, so the furnace will operate continuously without the necessity of evacuating the entire vacuum changer for every batch.

For further information circle No. 35 on literature request card, p. 34-B.

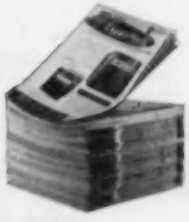
BARBER COLMAN

NEW Wheelco Model 405 Capacitrol


"Micropositioner" eliminates slide-wires
Modern design . . . new control concepts
Simple nonmechanical system for controlling fuel-fired furnace or oven
Line
Barber-Colman HYCC Valve Operator
Fuel Valve

Exclusive Wheelco development improves and simplifies proportioning control!

Ready right *now* for immediate delivery to you is the *all-new* Wheelco Model 405 Capacitrol that is causing more country-wide interest than any new instrument in years . . . the only truly simplified, entirely non-mechanical proportioning control form for fuel-fired equipment . . . the first completely modern controller that gives you all latest instrument design features at a real money-saving price. An ultra-sensitive polarized relay for positioning the control valve actuators, Wheelco's new "Micropositioner" is an integral part of the "plug-in" *electronic* circuit . . . a stand-out feature that gives you *true* proportioning control without complex equipment!



Write for complete facts

Write or ask your Wheelco Representative for Bulletin F-6493 . . . the complete story of the pace-setting changes this new Capacitrol brings to instrument users.

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When you make hollow parts

WHAT'S NEW
IN MANUFACTURERS' LITERATURE

41. Abrasion Tester
New bulletin 5409 on new model standard abrasion testing set describes machine and its operation. *Taber Instrument Corp.*

42. Abrasive Cleaning
Catalog 54-W on brush types, sizes, speeds, filaments. Aids to power brush selection. *Pittsburgh Plate Glass, Brush Div.*

43. Abrasive Wheels
Operating suggestions and recommended wheels for finishing stainless. *Manhattan Rubber Div.*

44. Allowable Stresses
Data Card 154 gives max. allowable stress values for 22 types of steel tubing. Formulas for calculation of max. working pressures. *Babcock & Wilcox*

45. Alloy Castings
22-page bulletin 2041 on heat and corrosion resistant castings. *Blaw-Knox*

46. Alloy Chart
Comparison of AISI, SAE, ACI, AMS, WAD and PWA chromium and chromium-nickel stainless specifications. *Cannon-Muskegon*

47. Alloy Hearth
Bulletin 112 on cast Ni-Cr hearth for heat treating furnaces. *Fahralloy*

48. Alloy Selection
Chart to select alloy for given corrosive problem. 350 corrosives included. *Cooper Alloy Foundry*

49. Alloy Specifications
Charts of chemistry, properties, specification designations of copper and aluminum alloys and babbitts. *Lavin*

50. Alloy Steel
14-page bulletin on two chromium-nickel alloy steels. Properties, working instructions, heat treatment, recommended uses. *Carpenter Steel*

51. Aluminum
Brochure with actual aluminum part attached gives advantages of aluminum for screw machine stock. *Kaiser Aluminum & Chemical Sales*

52. Aluminum Bonding
Brochure on Alumi-coat process of bonding aluminum and its alloys to ferrous metals. *Arthur Tickle Eng'g. Works*

53. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

54. Aluminum Finish
Bulletin on new invisible finish for aluminum describes Alodine No. 1000 and includes flow sheet for immersion process. *American Chemical Paint*

55. Aluminum Heat Treating
8-page Bulletin 5912 on solution heat treating, annealing, stabilizing and aging of aluminum. *General Electric*

56. Ammonia for Heat Treat
Booklets on "Applications of Dissociated Ammonia", "Ammonia Installations for Metal Treating", "The Nitriding Process", "Carbonitriding". *Armour*

57. Annealing Titanium
Data on annealing titanium parts in a high vacuum furnace. *High Vacuum Equipment Corp.*

58. Atmosphere Equipment
Bulletin GEA-2948 on ammonia dissociator. *General Electric*

59. Atmosphere Furnace
Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

60. Austempering
Data on austempering after gears have been finish machined. *Ajax Electric*

61. Be-Cu, Wrought
"Applications Unlimited", collection of case histories on successful uses of wrought beryllium copper. *Beryllium Corp.*

62. Bearings
New 44-page catalog and manual on self-lubricating products including bearings, bushings, machine parts. *Wakefield Bearing Corp.*

63. Black Oxide Coatings
8-page booklet on black oxide coatings for steel, stainless steel and copper alloys. *Du-Lite*

64. Bonded Metals
Data on advantages of parts of bonded aluminum and steel. *Al-Fin Div.*

65. Brass
80-page book on properties and uses of brass forgings, sand castings, rods and machinings. *Mueller Brass*

66. Brass Wire
10-page booklet gives properties, finishes, chemistry of extruded cold heading brass and copper wire. *Chase*

67. Brazed Tubing
12-page data book on brazed tubing made from copper coated steel. *Bundy*

68. Brazing
Bulletin 124—on salt bath brazing process—shows how it is possible to substitute brass for copper and develop joints of adequate strength for most steel assemblies. *Ajax Electric*

69. Brazing Titanium
Data sheet on use of a new flux for brazing titanium. *Handy & Harman*

70. Brinell Machine
Data on semi-automatic Brinell testing machine. *Detroit Testing Machine*

71. Bronze
12-page bulletin on properties and uses of continuous cast bronze rod and tube. *American Smelting & Refining*

72. Burners
Bulletin gives operation, applications, dimensions, output of oil burners. *Thermal Research & Engineering Corp.*

73. Carbides
84-page catalog of sintered carbides, hot pressed carbides, cutting tools, drawing dies, wear resistant parts. *Metal Carbides*

74. Carbon and Graphite
20-page catalog on carbon and graphite applications in metallurgical, electrical, chemical, process fields. *National Carbon*

75. Carbon Control
Bulletin SC-168 on system for automatically controlling carbon potential in continuous and batch furnaces. *Surface Combustion Corp.*

76. Carbon Control
Technical report on instrument for control of carbon potential of furnace atmospheres. *Lindberg Eng'g*

77. Carbon Steel Castings
Data folders on four types of carbon steel castings. Composition, properties, hardenability bands, uses. *Unitcast*

40. Ductile Iron

Each of the seven types of ductile iron are described in detail in this 32-page book. Beginning with an explanation of what ductile iron is, the discussion then goes on to tell of its cost, toughness, castability, wear resistance, machinability, welding and heat

treatment. Graphs compare its mechanical properties with other cast irons and steel. Its applications are illustrated and summarized in a 2-page chart. A Buyer's Guide, which accompanies the book, lists foundries in various states which supply ductile iron, types they cast and capacity of foundry. *International Nickel Co.*

78. Carburizing
Data on new autocarb furnace for gas carburizing and carbonitriding. *Sunbeam Corp.*

79. Castings
4-page folder on specialty carbon and alloy steel castings. *Farrell-Cheek Steel Co.*

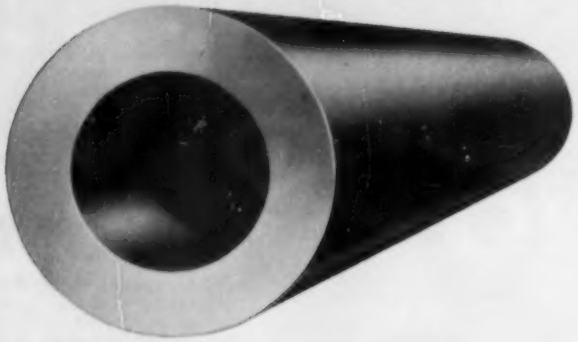
80. Castings, Bronze
16-page booklet on sand and centrifugal castings. *American Non-Gran Bronze*

81. Centrifugal Castings
Folder on centrifugal castings of heat, corrosion and abrasion resistant alloys, nonferrous metals, carbon and low alloy steels. *Sandusky Foundry & Machine*

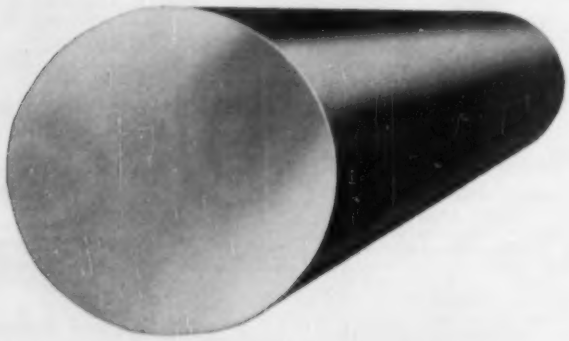
82. Charging
12-page brochure on eight models of charging machines for heating and melting furnaces. *Salem-Brosius*

When you make hollow parts . . .

Start with seamless tubing



instead of bar stock



Save steel, machining time!

WHEN you make hollow parts from bar stock, you waste time boring the center hole—you waste steel because you have to throw away the chips you bore out. Why not do it the easy, economical way? Start with Timken® seamless tubing. The hole's already there! Finish boring is often the first production step. You cut machining time—get more parts per ton of steel.

With Timken seamless tubing, your machine tools are more productive. Screw machine stations normally used for drilling can be released for other jobs. You get added machine capacity without additional machines.

To make sure you save even *more* steel, our engineers will study your problem and recommend the most economical tube size for your hollow parts job, guaranteed to clean up to finish dimensions.

You also get the highest internal quality with Timken seamless tubing. The piercing process by which it's made is basically a forging process. Result: a uniform spiral grain flow for greater strength and a refined grain structure which brings out the best quality of the metal. And the Timken Company's rigid control keeps the quality uniform from tube to tube and heat to heat. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH

SPECIALISTS IN FINE ALLOY STEELS, GRAPHITIC TOOL STEELS AND SEAMLESS TUBING

83. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

84. Cleaners
Bulletins on di-phase cleaners, specifications, equipment, advantages. *Solventol*

85. Cleaning
Bulletin on finishing and cleaning prior to electroplating by pressure blasting. *Cro-Plate Co.*

86. Cleaning
Data sheets on acid activators to promote removal of scale and oxides from steel and iron. *Swift Ind. Chem.*

87. Cleaning
12-page bulletin on fundamentals of metal cleaning contains data on types of cleaners, cleaning prior to plating, painting, enameling. Types of cleaning used for different products. *Metalwash Machinery*

88. Cleaning
44-page booklet, "Some Good Things to Know About Metal Cleaning," discusses tank, barrel and machine cleaning, pickling, zinc phosphate coating, rust prevention and other processes. *Oakite*

89. Cleaning Aluminum
Set of seven data sheets on cleaning and finishing of aluminum. *Pennsalt*

90. Coil Splicer
Bulletin 43 on automatic welding coiled material end to end. *E. W. Bliss*

91. Cold Rolled Steels
32-page booklet on stainless, alloy and carbon spring steels, and other specialties. Melting, temper, finishes. *Crucible Steel*

92. Combustion Control
20-page booklet on combustion of various fuels and portable instrument to measure content of oxygen and combustibles. *Cities Service Oil*

93. Compressors
12-page bulletin 126-A on application of turbo compressors to oil and gas-fired equipment used in heat treating, agitation, cooling, drying. Performance curves, capacities. *Spencer Turbine*

94. Continuous Casting
24-page book, "Better by the Mile", describes how the Rossi continuous casting machine works. History of continuous casting. *Scovill Mfg.*

95. Controllers
80-page Catalog 8305 on nonindicating electric, electronic and pneumatic controllers for temperature, pressure and humidity. *Minneapolis-Honeywell*

96. Copper Plating
24-page book on bright copper-plating process. Process control, analytical procedures, barrel plating are discussed. *Lea Mfg. Co.*

97. Corrosion Resistant Alloy
20-page booklet on nickel, chromium, molybdenum, iron alloy gives chemical composition, corrosion data, properties and welding characteristics. *Haynes Stellite*

98. Creep Testing
Data on operation and instrumentation of Arcweld lever arm creep testing machine. *Minneapolis-Honeywell*

99. Crystal Models
Folder describes unique kit for constructing crystal models. *Harshaw*

100. Cutting
New bulletin on cutting torches, one using acetylene and the other propane. *Universal Cutting & Welding Equipment*

101. Cutting and Grinding
16-page booklet on cutting fluids and coolants. Includes section chart. *Johnson Wax*

102. Cutting Oil Chart
Selection chart for seven classes of metal in nine machining operations. *Aldridge Industrial Oils*

103. Deburring
Bulletin on deburring by pressure blast and equipment for wet pressure blasting. *Cro-Plate Co.*

104. Degreasing
34-page booklet on vapor degreasing. Design, installation, operation and maintenance of equipment. *Circo Equipment*

105. Descaling
24-page book "Handling Metallic Sodium" with special reference to sodium hydride descaling. *U. S. Ind. Chem.*

106. Descaling Stainless Steel
Bulletin 25 on descaling stainless steel and other metals in molten salt. *Hooker Electrochemical*

107. Dew Point Control
Bulletin No. 21-C on instrument which indicates, records and controls dew point automatically. *Ipsen*

108. Diamond Wheel
Bulletin on advantages of diamond wheel grinding. *Action Diamond Tool Co.*

109. Die Casting
Bulletin on automatic pouring unit for aluminum die castings. *Ajax Engineering*

110. Die Castings
20-page bulletin on the process, design and construction. Uses of die castings. *Precision Castings Co.*

111. Die Castings
30-page booklet of pressure die casting, permanent mold casting and centrifugal casting of copper base alloys. *Pressco Casting & Mfg.*

112. Die Designs
Attractive 32-page booklet describes design of dies for upsetting forging machines. *Ajax Manufacturing Co.*

113. Dilatometer
Catalog Micro 8161 on equipment for thermal analysis of metals, ceramics. *Leitz*

114. Electric Furnace
Bulletin on box-type, pre-heat and hardening furnace with automatic atmosphere contamination control. *Pacific Scientific*

115. Electric Furnaces
Bulletin on specially designed continuous production furnaces for brazing, sintering, bright annealing, heat treating, bar heating, melting, forging. *Harper Electric Furnace Corp.*

116. Electric Furnaces
Brochure on electric heat treating, melting, metallurgical tube, research and sintering furnaces. *Pereny Equipment*

117. Electric Furnaces
New bulletin on electric heat treating furnaces gives summary of progress in furnace developments. *Holcroft*

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121. Extensometer
8-page bulletin on extensometers for sheet metal and wire, compressometers, defectometers and other accessories. *Baldwin-Lima-Hamilton*

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12-page circular on aluminum extrusion process contains selection data. Process described. Advantages. *Precision Extrusions*

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130. Flame Plating
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Bulletin 201 on flow meter for gas used in heat treating. *Waukee Eng'g*

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148. Furnaces
Bulletin on reverberatory furnaces for aluminum, aluminum alloys and die casting metals. *Eclipse Fuel Eng.*

149. Furnaces
Bulletin No. 200 on multi-burner heat treating furnace. *Am. Gas Furnace*

150. Furnaces, Heat Treating
Catalog on furnaces for tool room and general purpose heat treat. *Cooley*

151. Furnaces, Heat Treating
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Physical, thermal, chemical, electrical, diffusion and optical properties of electroplated gold. Uses. *Technic, Inc.*

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Chemical and physical data on chromium, nickel, cobalt, molybdenum alloy as hard surfacing wire or in cast form. *Coast Metals*

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20-page bulletin on use of portable hardness testers and accessories. *Ames Precision Machine*

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4-page bulletin on tester for both superficial and regular hardness testing. *Torsion Balance Co.*

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Bulletin No. A-12 on new Wolpert-Gries machine for making Rockwell hardness tests. *Gries Industries*

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12-page brochure No. 790 on vacuum furnaces for melting and casting titanium, zirconium, germanium, copper, iron and steel. Also furnaces for annealing, hardening, brazing. *F. J. Stokes*

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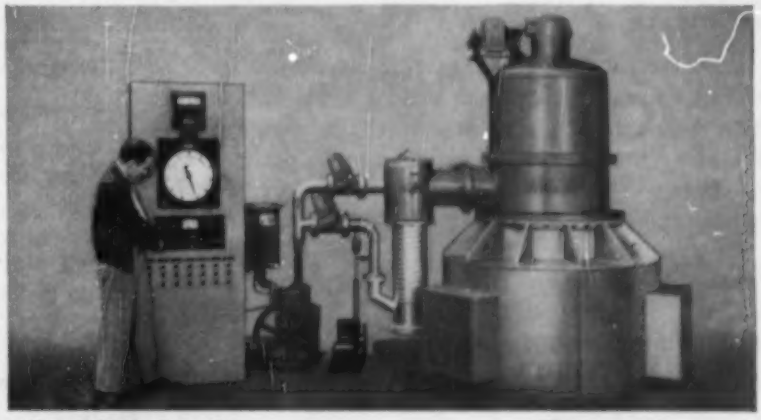

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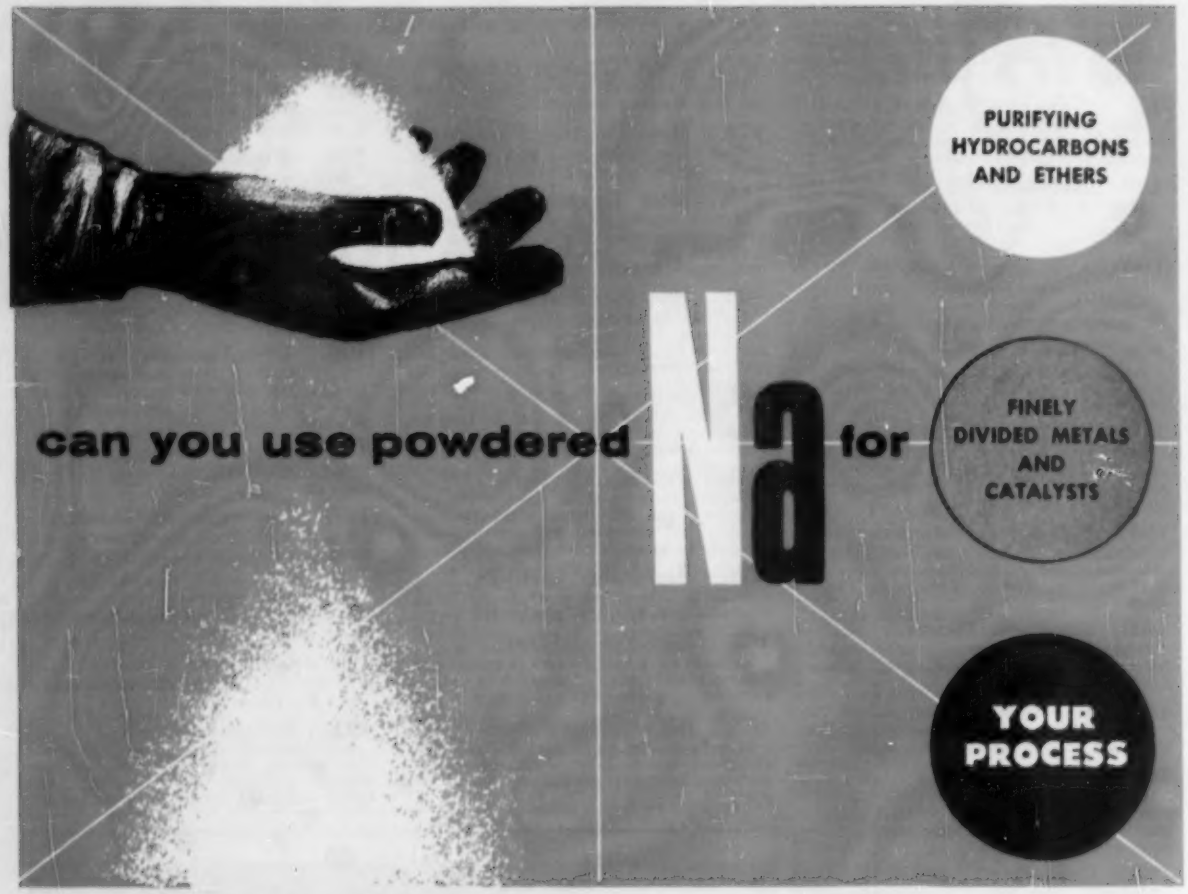

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New 8-page booklet on production of lead treated steels, their advantages and case histories of their use. *Copperweld Steel Co.*

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208. Low-Alloy Steel
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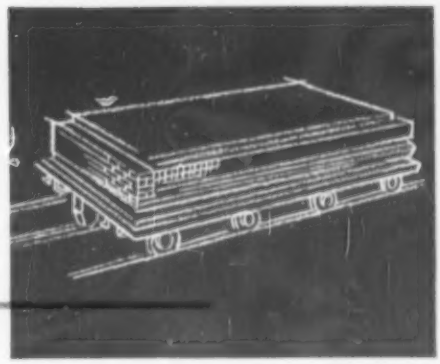

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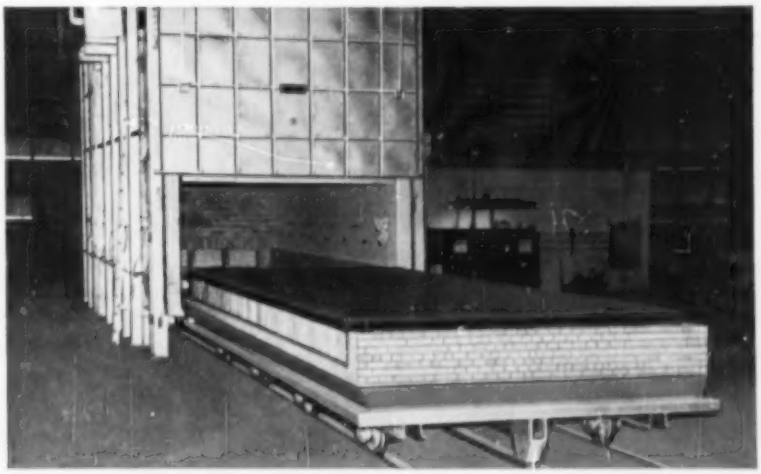

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CMP COLD ROLLED STRIP STEEL

(NON-SCALLOPING QUALITY)

eliminated earing and an extra operation ..stepped up production

BEFORE

Buying a standard specification cold rolled strip steel, this manufacturer had several fabrication problems. Needing a precision assembly fit with other components, they frequently had runs of many rejects and production slow-downs. Inspection costs for in-process fabricating were excessive. Each unit, after drawing, also required an additional trimming operation to remove the ears. Because of the uniformity needed, costs were running out-of-line and the added manual work to reclaim rejects was further increasing costs.

AFTER

First, a suggestion from a CMP representative gained interest and established several meetings with production and engineering to consider the CMP proposal. Several test runs were made with the non-earring CMP specification steel developed specifically for this job. It worked wonders. The trimming operation was eliminated completely and a precision quality for uniformity was established. A close, dependable assembly of components was made possible, eliminating the "re-work" line entirely. Rejects were reduced to an absolute minimum. Perhaps you could improve your product and production, too, with CMP "specific specs" cold rolled strip steel — we will be glad to work with you.

the Cold Metal Products co.

GENERAL OFFICES: YOUNGSTOWN 1, OHIO

PLANTS: YOUNGSTOWN, OHIO AND INDIANAPOLIS, INDIANA

SALES OFFICES: New York • Cleveland • Detroit • Indianapolis • Chicago • St. Louis • Los Angeles • San Francisco

LOW CARBON, HIGH CARBON (Annealed or Tempered), STAINLESS AND ALLOY GRADES, ELECTRO ZINC COATED ARE AVAILABLE FROM:

THE COLD METAL PRODUCTS CO. OF CALIFORNIA
2131 South Garfield Avenue, Los Angeles — Phone: RAymond 3-4581

THE KENILWORTH STEEL CO., 750 Boulevard, Kenilworth, New Jersey
Phones: N. Y., COrtlandt 7-2427; N. J., UNionville 2-6900

PRECISION STEEL WAREHOUSE, INC.
4425 W. Kinzie, Chicago — Phone : COlumbus 1-2700

272. Stainless S

20-page catalog on c applications and work of 20% chromium-29 steels, with and witho *penter Steel*

273. Stampings

Data on how stamp time and money. *J. H*

274. Steel

Stock book of carb alloy steel, tubing, a data including color co perature guide, gage c *Supply*

275. Steel

256-page handbook lengths, steels availab mechanical properties compositions, hardne versions. *Ryerson*

276. Steel 5210

New stock list on and ring forgings. *Pet*

277. Stiffness T

Data on stiffness te six ranges. *Taber Inst*

278. Straighten

16-page bulletin on stretcher levelers; hov ing works. *Contine Machine*

279. Surface P

Bulletin on imports face preparation. Me duce surface that wil *Metalweld, Inc.*

280. Temperatu

Bulletin F-6149 on t tems, and how to s for your purposes. W

281. Test Acce

22-page Bulletin 46 tools and accessories ing machines. *Tinius*

282. Test Bars

New 18-page bulleti of test bar patterns, bars, testing proc *Metals Div., America fining Co.*

283. Test Cabi

New 4-page bulleti cabinets for testing a −200 to +300° F. *Tr ture Products*

1	25	49	73	
2	26	50	74	
3	27	51	75	
4	28	52	76	
5	29	53	77	
6	30	54	78	
7	31	55	79	
8	32	56	80	
9	33	57	81	
10	34	58	82	
11	35	59	83	
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17	41	65	89	
18	42	66	90	
19	43	67	91	
20	44	68	92	
21	45	69	93	
22	46	70	94	
23	47	71	95	
24	48	72	96	

Stainless Steel

catalog on corrosion resistance, ns and working characteristics chromium-29% nickel stainless h and without columbium. *Carel*

Stampings

how stamped assemblies save money. *J. H. Sessions*

Steel

ook of carbon steels, stainless, l, tubing, aluminum; technical ding color codes, heat treat temguide, gage chart, etc. *U. S. Steel*

Steel

handbook lists sizes, weights, teels available, shapes. Data on al properties, standard steel ons, hardness numbers con*Ryerson*

Steel 52100

ock list on 52100 tubing, bars, forgings. *Peterson Steels*

Stiffness Testing

stiffness tester which tests in s. *Taber Instrument Corp.*

Straightening Machines

bulletin on shape straighteners, levelers; how shape straightenks. *Continental Foundry &*

Surface Preparation

on importance of proper surparation. Methods used to proace that will insure good bond. l, *Inc.*

Temperature Control

F-6149 on types of control sysl how to select the right one purposes. *Wheelco*

Test Accessories

Bulletin 46 on instrumentation, accessories for mechanical testines. *Tinius Olsen*

Test Bars

-page bulletin No. 168 on design ar patterns, production of test sting procedures. *Federated iv., American Smelting and Re-*

Test Cabinets

page bulletin on three types of or testing at temperatures from +300° F. *Trop-Arctic Temperaucts*

284. Test Cabinets

New 6-page catalog on environmental testing equipment—temperature, humidity, sand and dust, explosion, rain and sunshine, altitude. *American Research Corp.*

285. Testing Machines

Bulletin on Brinell hardness, ductility, compression, tensile, universal, transverse, hydrostatic proving instruments. *Steel City Testing Machines*

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16-page booklet on advantages and applications of textured metal. *Rigidized Metals*

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New bulletin on general application data for various types of elements and different metals. *Claud S. Gordon Co.*

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New bulletin on thermocouple wire and thermocouple extension wire lists sizes, metals, insulations. *Claud S. Gordon*

289. Thickness Tester

Bulletin on battery operated, portable thickness tester for measuring from one side. Principles of operation. *Branson Instrument*

290. Tin

Folder on uses of tin for lubricating, as a fusing agent, barrier, opacifier, fixative, stabilizer, pesticide. *Malayan Tin Bureau*

291. Titanium

30-page data book on properties of commercially pure and alloy titanium, melting, forging and rolling. 16 charts and micros; 4 hardness conversion curves for titanium. *Republic Steel*

292. Titanium and Zirconium

16-page bulletin, "The Hydrimet Process", on titanium and zirconium metals and hydrides, and other metallurgical hydrides. *Metal Hydrides*

293. Titanium Foil

Bulletin 100 on pure titanium foil gives properties, tolerances, composition. Data on welding, brazing, annealing and forming. *American Silver Co.*

294. Tool and Die Steels

26-page book on six oil and air hardening steels for high-production tools and dies. Many uses illustrated. *Bethlehem Steel*

295. Tool Steel

12-page booklet on carbon-vanadium tool steels. Compositions, microstructures, heat treatment. *Vanadium-Alloys Steel*

296. Tool Steel

Bulletin on precision-ground oil-hardening and air-hardening tool steel flat stock. *Jessop*

297. Tool Steel

36-page booklet on properties and applications of high speed steels, nonferrous cutting materials and carbides. *Allegheny Ludlum*

298. Tool Steel Selector

Twist the dial of the 9-in. circular selector and read off the tool steel for your application. *Crucible Steel*

299. Tubing

52-page "Handbook of Seamless Steel Tubing". 26 pages of data. *Timken*

300. Vacuum Calculator

Slide rule for quick calculation of data necessary in vacuum engineering and processing—for instance, pump capacities and time to reach given vacuum. Pertinent conversion tables on back. *F. J. Stokes Machine*

301. Vacuum-Melted Metals

Data on alloys available and their physical properties. *Carboloy Dept., General Electric Co.*

302. Welding

10-page bulletin on welding technique involving use of weld insert. *Arcos*

303. Welding Alloy Steel

44-page Data Book 4D covers all types of welding of nickel alloy steels. *International Nickel*

304. Welding Equipment

Catalog on Cadweld process and arc-welding accessories. *Erico Products*

305. Wire Cloth

84-page booklet on applications, meshes, baskets, filters. *Cambridge Wire Cloth*

306. Zinc Analysis

Article on quantitative spectrographic analysis on zinc die-casting alloy, from Spectrographer's News Letter. *Allied Research Laboratories.*

307. Zinc Die Casting

New 24-page booklet on zinc for die castings and applications of die castings. *St. Joseph Lead Co.*

308. Zirconia

Folder on new, patented process in which each zirconia crystal is stabilized. Characteristics of stabilized zirconia. *Zirconium Corp. of America*

January, 1955

49	73	97	121	145	169	193	217	241	265	289
50	74	98	122	146	170	194	218	242	266	290
51	75	99	123	147	171	195	219	243	267	291
52	76	100	124	148	172	196	220	244	268	292
53	77	101	125	149	173	197	221	245	269	293
54	78	102	126	150	174	198	222	246	270	294
55	79	103	127	151	175	199	223	247	271	295
56	80	104	128	152	176	200	224	248	272	296
57	81	105	129	153	177	201	225	249	273	297
58	82	106	130	154	178	202	226	250	274	298
59	83	107	131	155	179	203	227	251	275	299
60	84	108	132	156	180	204	228	252	276	300
61	85	109	133	157	181	205	229	253	277	301
62	86	110	134	158	182	206	230	254	278	302
63	87	111	135	159	183	207	231	255	279	303
64	88	112	136	160	184	208	232	256	280	304
65	89	113	137	161	185	209	233	257	281	305
66	90	114	138	162	186	210	234	258	282	306
67	91	115	139	163	187	211	235	259	283	307
68	92	116	140	164	188	212	236	260	284	308
69	93	117	141	165	189	213	237	261	285	
70	94	118	142	166	190	214	238	262	286	
71	95	119	143	167	191	215	239	263	287	
72	96	120	144	168	192	216	240	264	288	

METAL PROGRESS,

7301 Euclid Avenue, Cleveland 3, Ohio

Please have literature circled at the left sent to me.

Name

Title

Company

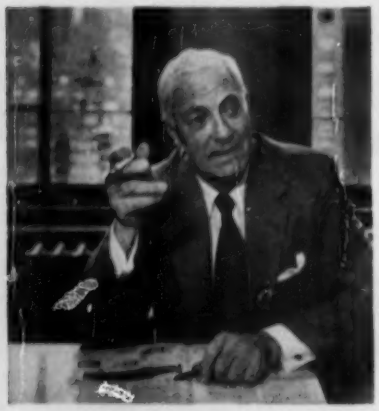
Address

City and State

Postcard must be mailed prior to Apr. 1, 1955
Students should write direct to manufacturers.

How Do Lightweight Refractories Cut Fuel Costs And Boost Furnace Output?

Here, certainly, is a timely question. There's a heavy squeeze today on most furnace operators for lower costs, larger production . . . or both. And despite all the economies they've put into effect so far, they're still searching hard for ways to make their furnace dollars do a bigger job.



The following discussion brings out a number of facts, often overlooked, about the money-saving, profit-building potentials inherent in *lightweight* insulating firebrick.

Q. *First of all, just what do you mean by "lightweight" insulating firebrick?*

A. Compared with dense, fireclay brick weighing approximately 7½ to 8½ pounds each, insulating firebrick range from about 3½ pounds down to slightly over 1 pound for various temperature requirements.

Q. *What does this light weight have to do with lower production costs?*

A. Briefly, heavy furnace linings waste your fuel dollars two ways:

They soak up and store large quantities of heat which are lost when the furnace is cooled; and they conduct and lose too much heat through the wall.

Lightweight insulating firebrick, on the other hand, contain millions of tiny air cells, heat up and cool quickly, absorbing and storing very little heat. Also, they resist heat flow, keeping it inside the furnace to do productive work.

Q. *I can see why you would save on fuel — but how much?*

A. There's no single answer to that question — there are too many variables to be considered. But to give you an idea of these savings, here are a few actual examples:

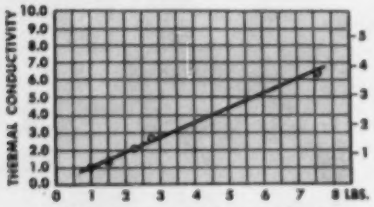
The operator of a large forge furnace cut his fuel costs more than 50% after changing to *lightweight* insulating firebrick.

A manufacturer of electric kilns states that insulating firebrick result in heat savings of fully 25%.

A magnesium melting crucible furnace that formerly used 1,000,000 BTU's per hour now does the same job with 500,000 BTU's, thanks to insulating firebrick.

Q. *Increased production has also been pointed out as an advantage of insulating firebrick. How do you explain this?*

A. Again the answer lies in lightness of weight. Because lightweight firebrick store and conduct less heat, they come up to operating temperature faster — cool down faster, too. This means — shorter heating cycles.



Relation between weight and thermal conductivity for several brands of kaolin base refractories. (mean temperature, 900F)

Secondly, because lightweight firebrick conduct far less heat than heavy, dense firebrick, you don't have to build as thick a wall. This gives you more hearth area per square foot of floor space.

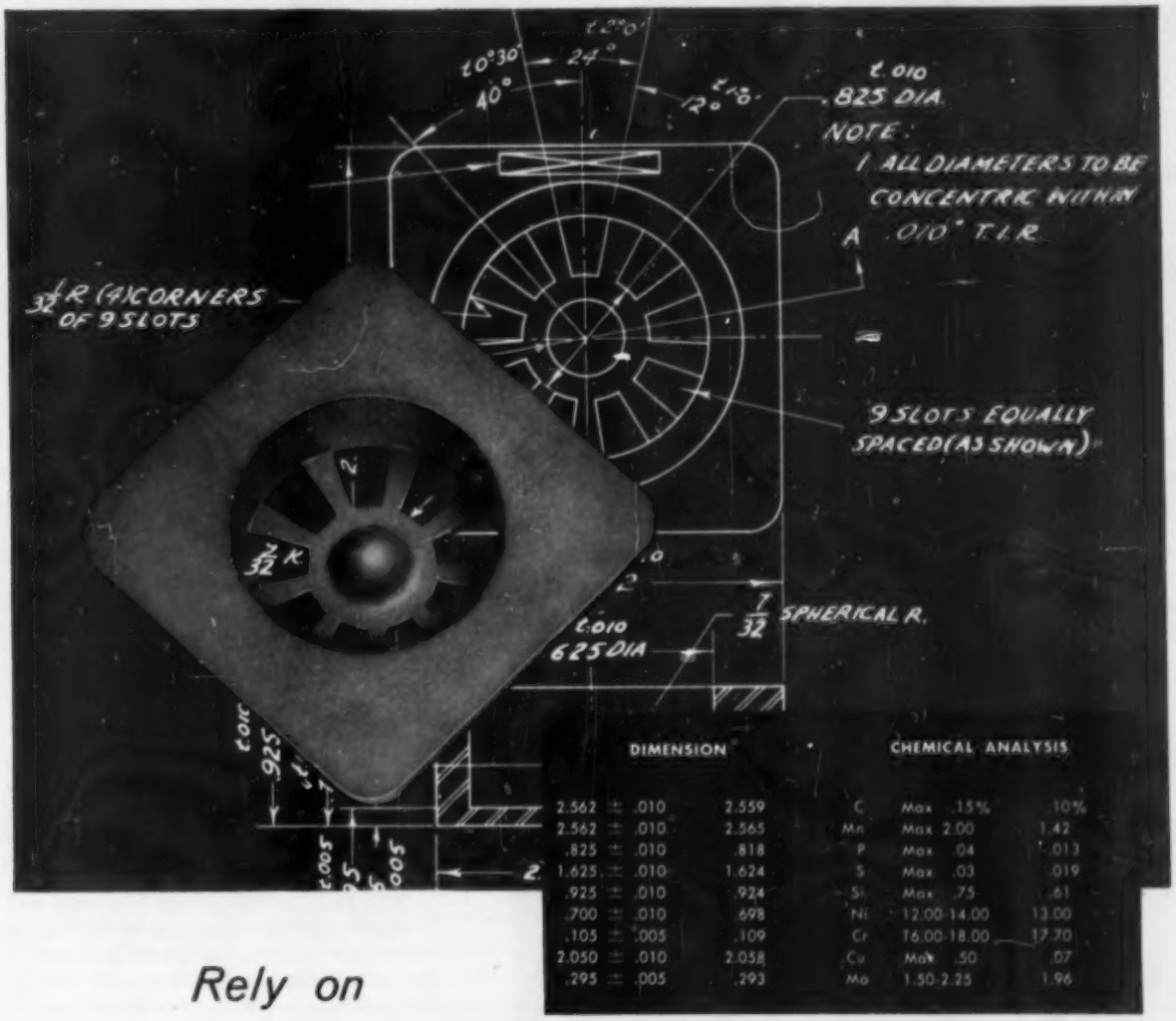
Thirdly, lightweight firebrick respond more rapidly to changes in furnace heat input, which means closer temperature control and fewer rejects in many instances.

It's just like adding extra furnace capacity without adding to your furnace investment.

Q. *Are there any differences in the performance of the various brands of insulating firebrick available?*

A. Naturally, the *lighter* the brick the greater the fuel savings and furnace output. And the lightest insulating firebrick of all, for any temperature range — if you'll pardon our mentioning it — are B&W Insulating Firebrick.

THE BABCOCK & WILCOX CO.
Refractories Division
General Offices:
161 East 42nd St., New York 17, N. Y.
Works: Augusta, Ga. R-606



DIMENSION			CHEMICAL ANALYSIS			
2.562 ± .010		2.559	C	Max .15%		10%
2.562 ± .010		2.565	Mn	Max 2.00		1.42
.825 ± .010		.818	P	Max .04		.013
1.625 ± .010		1.624	S	Max .03		.019
.925 ± .010		.924	Si	Max .75		.61
.700 ± .010		.698	Ni	12.00-14.00		13.00
.105 ± .005		.109	Cr	16.00-18.00		17.70
2.050 ± .010		2.058	Cu	Max .50		.07
.295 ± .005		.293	Mo	1.50-2.25		1.96

Rely on

Crucible ACCUMET investment castings

for dimensional and metallurgical accuracy . . .

This intricately shaped aircraft instrument part had to be held to rigid specifications both in size and in chemical analysis of the steel.

That's why Crucible ACCUMET® precision castings were used. For Crucible's *lost wax* method of casting, and its long experience as the country's leading producer of fine special purpose steels, combine to bring you accurate castings of the highest quality. But the two tables shown below actually tell the story better than words can. They show how closely ACCUMET castings are held to original specifications.

The next time you have a job where quality and close tolerances are needed, be sure to investigate the advantages of ACCUMET precision castings — *call Crucible.*

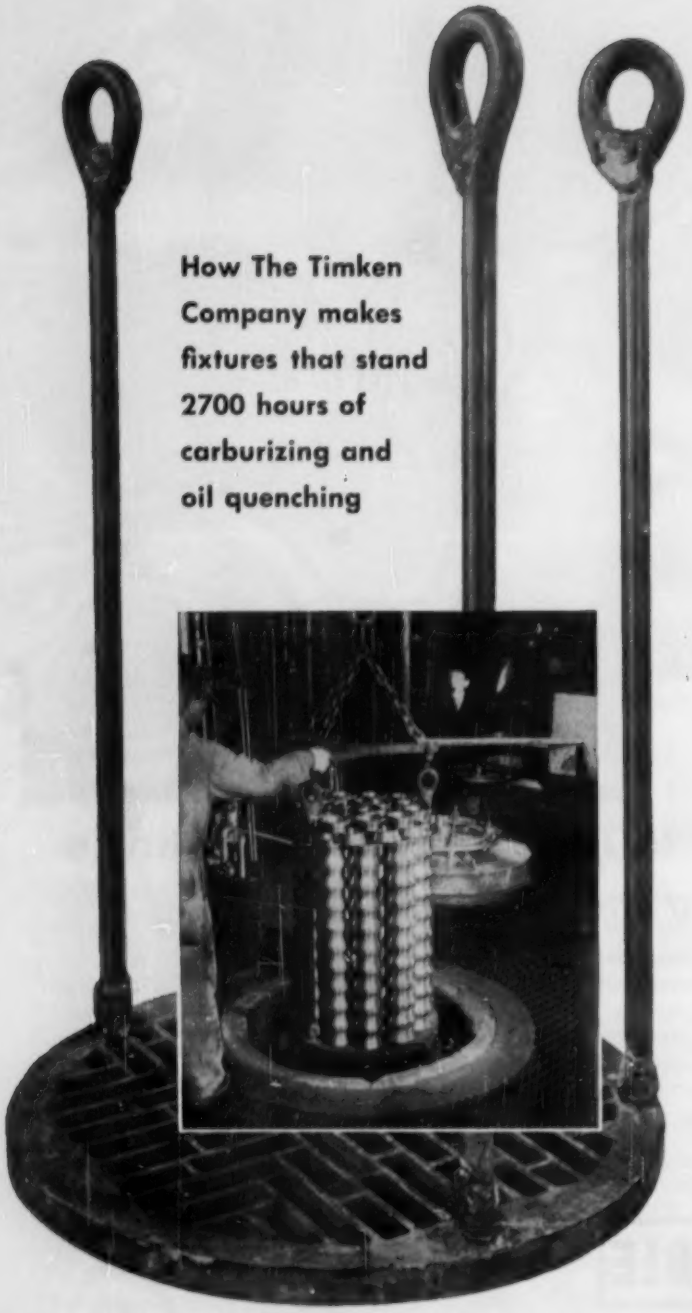
CRUCIBLE

first name in special purpose steels

54 years of Fine steelmaking **ACCUMET INVESTMENT CASTINGS**

CRUCIBLE STEEL COMPANY OF AMERICA, GENERAL SALES OFFICES, OLIVER BUILDING, PITTSBURGH, PA.

Service life doubled ...with Inconel



How The Timken Company makes fixtures that stand 2700 hours of carburizing and oil quenching

How long do *your* quenching fixtures last? And how much do they have to take? Perhaps the experience of The Timken Roller Bearing Company can help you save on replacement costs.

Roller bearing parts at The Timken Company are carburized in natural gas. This heat treatment is followed by an immediate oil quench.

During the whole process the parts are carried on a fixture consisting of three Inconel® eye-bolts welded to a grid. Formerly, under the corrosive conditions and severe thermal shock, eye-bolts only lasted an average of 1350 hours.

With Inconel, The Timken Company finds the service life of these eye-bolts has been doubled, and better. Some last up to 3700 hours.

This is possible because of Inconel's combination of valuable properties: its strength at high temperatures, its excellent resistance to oxidation and corrosion, and to thermal shock.

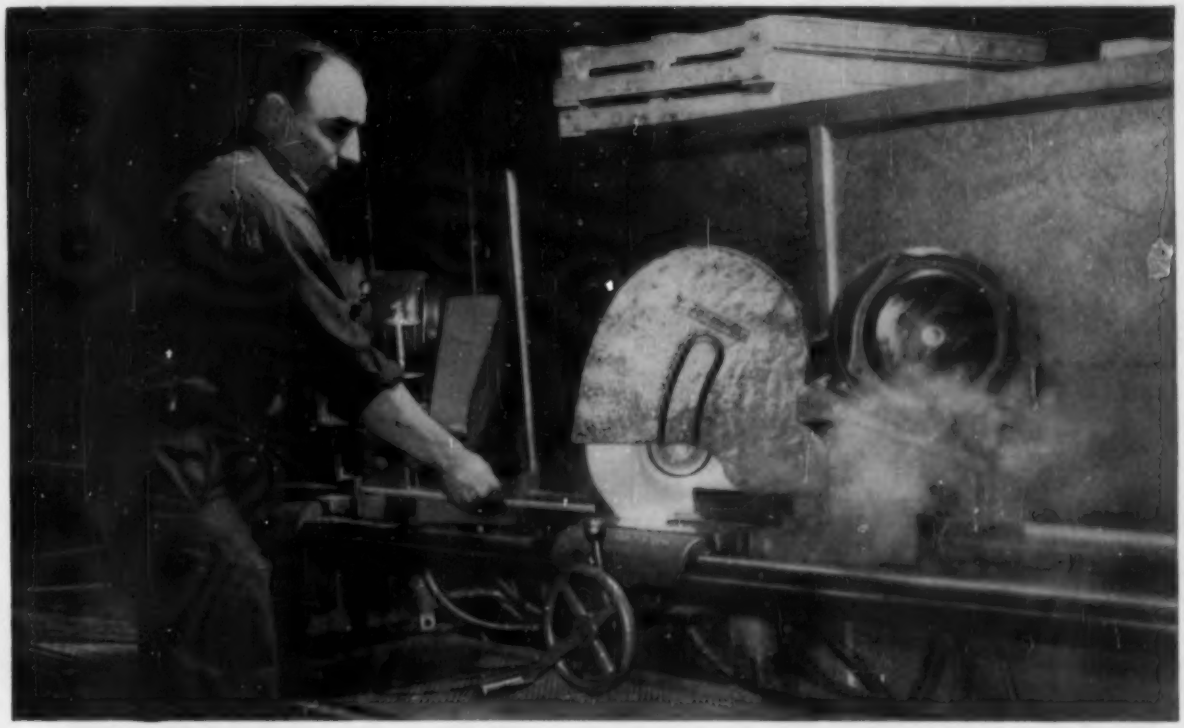
With these factors present, fabricated, well designed Inconel equipment is the logical choice for heat treating service followed by quenching. Of further importance, Inconel, despite its strength and toughness, can be readily formed. It is also easy to weld by any of the commonly used methods.

Try Inconel. You'll find, like The Timken Roller Bearing Company, that it is a high temperature alloy that gives long service under severe conditions. And for many suggestions on practical ways to make Inconel heat treating equipment write for our booklet, *Keep Operating Costs Down . . . When Temperatures Go Up.*

The INTERNATIONAL NICKEL COMPANY, Inc.
67 Wall Street New York 5, N. Y.

INCO TRADE MARK **Nickel Alloys**

Inconel *. . . for long life at high temperatures*



Aluminum Air Seal Mfg. Co. Reports:

"OUR PROBLEM WITH GRAVITY OILERS WAS SOLVED BY CITIES SERVICE CUTTING OIL!"

When flow of oil from gravity oilers was restricted by gum formation and residue, Aluminum Air Seal Mfg. Co. switched to Cities Service Chillo #22 Cutting Oil. Results: Plenty of oil flow, increased saw life, cleaner finish cuts!

Here's the report as Cities Service received it from D. C. Cover, Plant Supt. of Aluminum Air Seal Mfg. Co.:

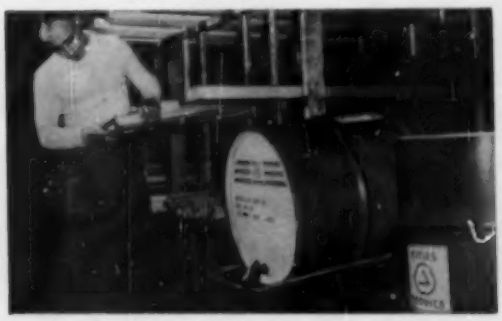
"For the past three years we have been using your Chillo #22 with excellent results.

"Prior to that time, we experienced considerable trouble because our gravity oilers were not functioning properly due to residue and gum formation which restricted the flow of cutting oil to the saw. Consequently, this inadequate supply of cutting oil permitted excessive wear which, of course, greatly reduced our saw life.

"At this time, a Cities Service Lubrication Engineer called on us and recommended Chillo #22 as a solution to this problem. Not only was the problem of adequate supply eliminated but we found the oil gave excellent saw life as well as clean finish cuts.

"As you know, we supply aluminum stock to Trim-a-Seal plants throughout the country. *Whenever a new plant is set up we recommend that they use your product for cutting because we know it will do the job.*"

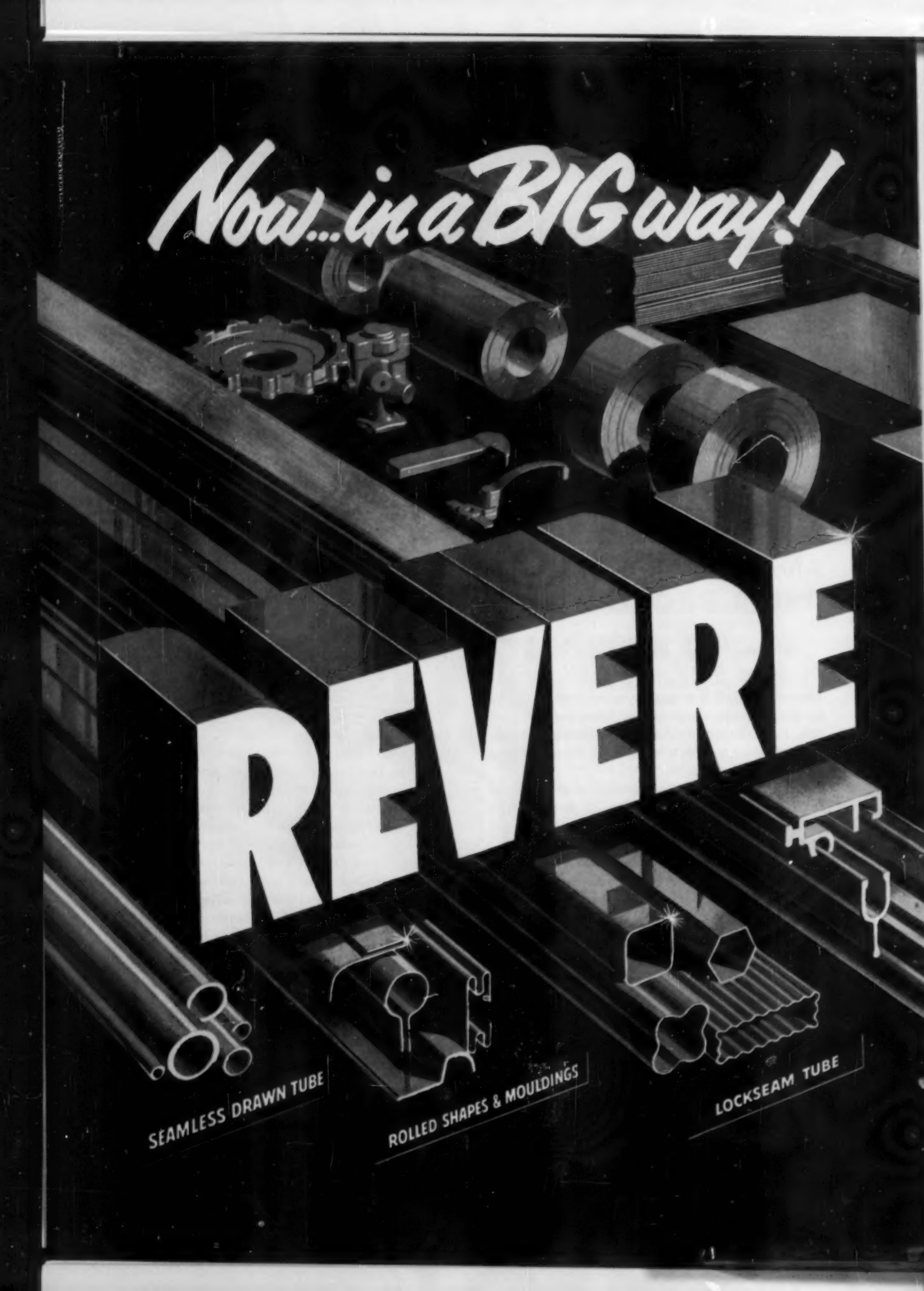
If you'd like to learn more about the oil "we know will do the job," contact your nearest Cities Service representative or write Cities Service Oil Company, Sixty Wall Tower, New York 5, N. Y.

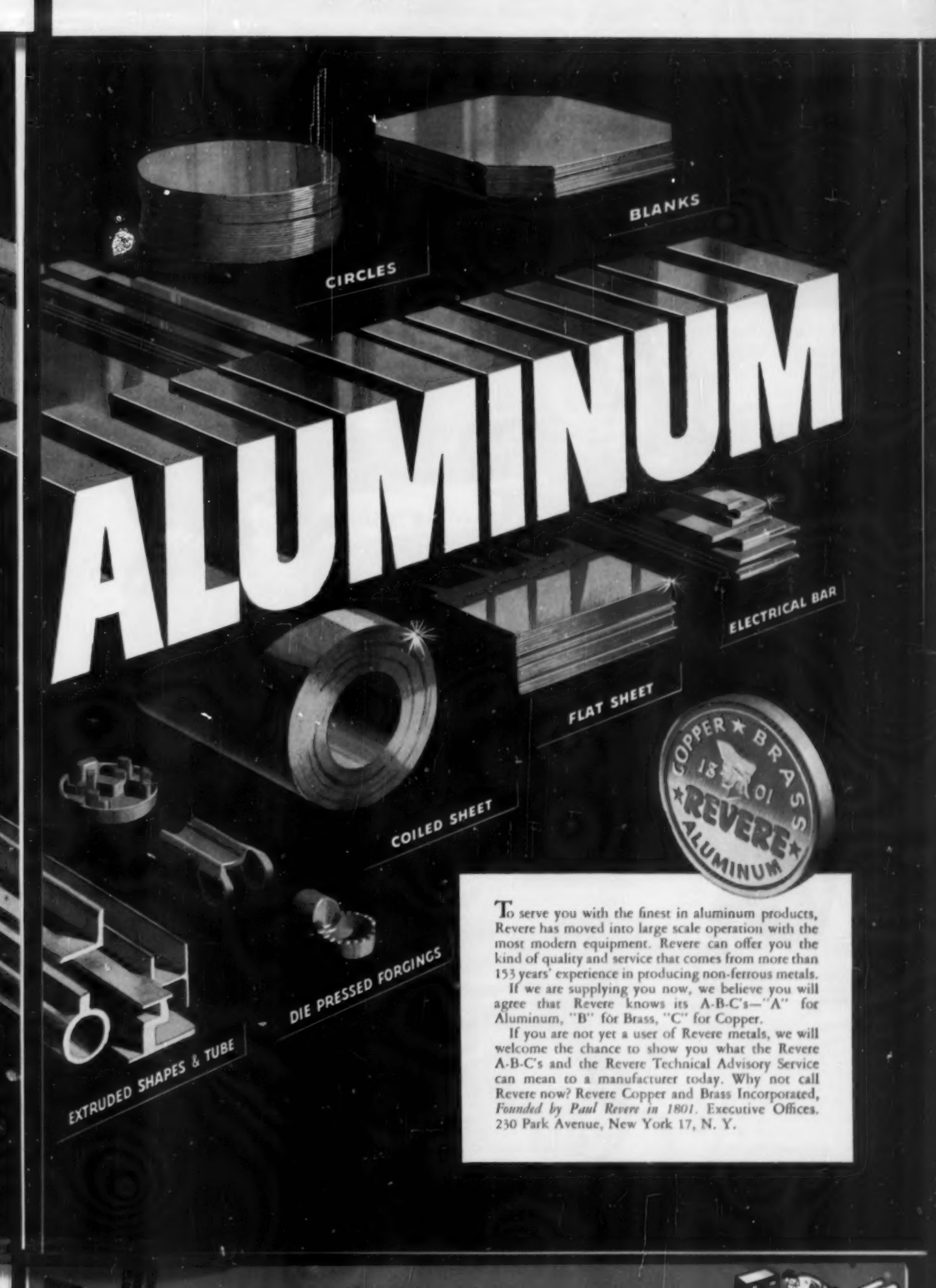


EXAMINING ALUMINUM EXTRUSION, an Aluminum Air Seal employee observes clean cut made with help of Cities Service Chillo #22 Cutting Oil. Firm supplies aluminum stock to 25 Trim-a-Seal plants throughout country.

CITIES SERVICE

QUALITY PETROLEUM PRODUCTS


Now...in a BIG way!
REVERE
SEAMLESS DRAWN TUBE
ROLLED SHAPES & MOULDINGS
LOCKSEAM TUBE

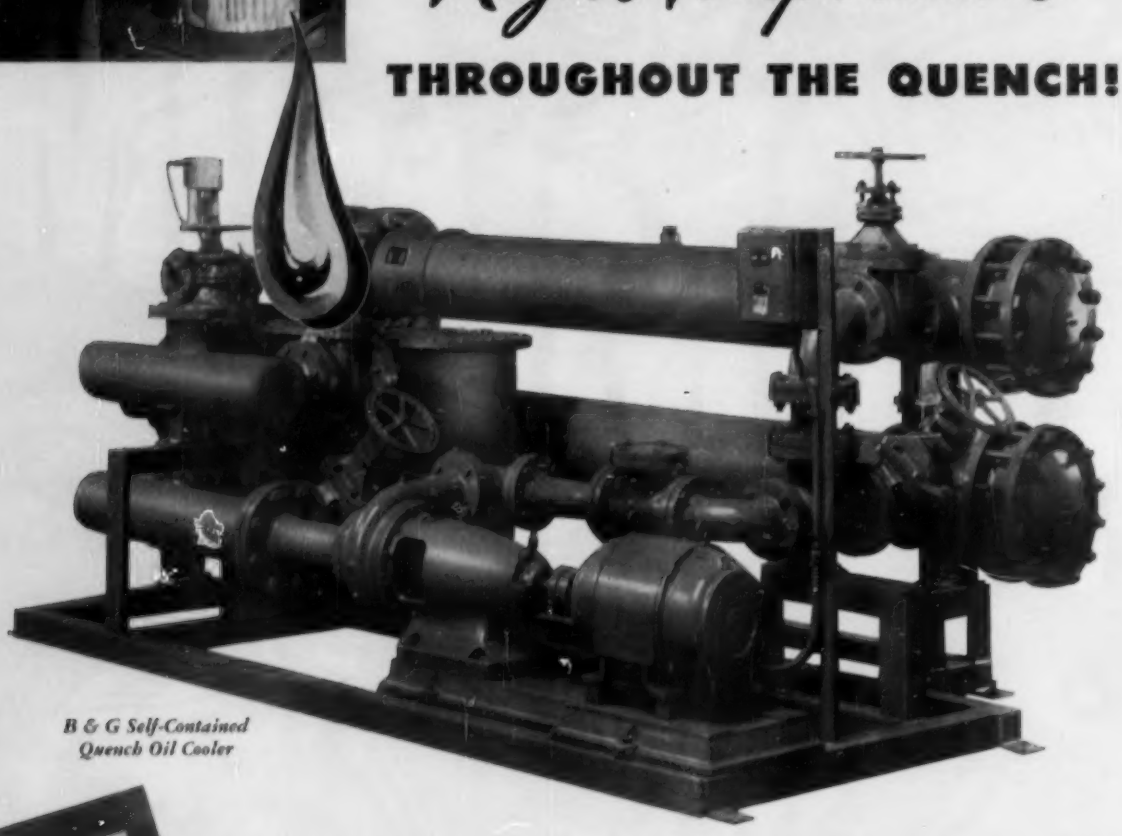


To serve you with the finest in aluminum products, Revere has moved into large scale operation with the most modern equipment. Revere can offer you the kind of quality and service that comes from more than 153 years' experience in producing non-ferrous metals.

If we are supplying you now, we believe you will agree that Revere knows its A-B-C's—"A" for Aluminum, "B" for Brass, "C" for Copper.

If you are not yet a user of Revere metals, we will welcome the chance to show you what the Revere A-B-C's and the Revere Technical Advisory Service can mean to a manufacturer today. Why not call Revere now? Revere Copper and Brass Incorporated, *Founded by Paul Revere in 1801.* Executive Offices, 230 Park Avenue, New York 17, N. Y.

EVERY DROP OF OIL AT THE *Right Temperature* THROUGHOUT THE QUENCH!



B & G Self-Contained Quench Oil Cooler

This combined Catalog and Selection Manual gives full information.

Old-fashioned, uncontrolled quenching methods may be costing you more than you realize. By installing a B & G *Hydro-Flo* Quench Oil Cooling System you can eliminate losses caused by excessive rejects—make an "inside profit" by cutting operating costs.

The "SC" Series *Hydro-Flo* Oil Cooler is completely self-contained—combining Cooler, Motor, Pump, Strainer and all controls in a single, integrated unit. Fully automatic, it keeps oil temperature at the desired degree through all stages of the quench.

Or, if you prefer, the component parts of a *Hydro-Flo* Oil Cooling System may be purchased and assembled on the job. In either case, you are assured of *uniform quality* in your product because of *uniform quenching conditions.*

Send for Catalog and Simplified Selection Manual.

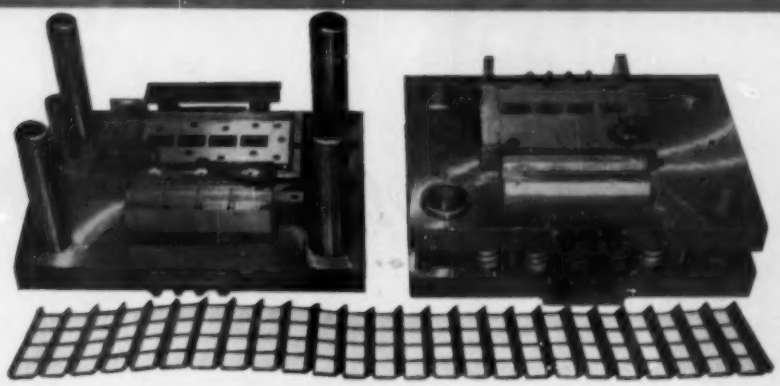
BELL & GOSSETT
COMPANY
Dept. DS-16, Morton Grove, Ill.

Canadian Licensee: S. A. Armstrong Ltd., 1400 O'Connor Drive, Toronto, Canada

Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. Export Distributor: Bethlehem Steel Export Corporation



Maker of Agricultural Machinery Gets Good Results With Lehigh H

The Gleaner Harvester Corp., Independence, Mo., has every reason to be proud of its revolutionary, self-propelled combine. For this mechanical marvel, with its centerline design, is a joy to behold as it takes large, continuous bites into blowing fields of grain.

Making parts for this practically human thresher and separator calls for some highly specialized dies made from outstanding tool steels. For example, the progressive die shown here, made of Bethlehem Lehigh H tool steel, produces the combine's straw rack (foreground). Operating in a 150-ton press, the die blanks and forms 22-gage galvanized sheet steel, about 50 strokes of the press being required to make each rack. The die is subjected to more than 20,000 strokes before inspection is required — ample proof of its durability.

Lehigh H is our high-carbon, high-chromium air-hardening tool-and-die steel. It's outstanding for long production runs because of its wear-resistance and toughness. Moreover, it offers minimum distortion during heat-treatment, plus the ability to harden deeply.

Lehigh H is safe-hardening. It is cooled in still air from a hardening temperature of 1850 F, and minimizes the cracking hazards of intricate dies, thin sections, and insufficient radii.

Your tool-steel distributor will be pleased to answer your questions about Lehigh H. He's always at your service.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

Carburization of Tools Can Be Detrimental

Widely known are the beneficial effects obtained by intentionally carburizing some tools during heat-treatment. In general, wear-resistance of the surface is increased, while at the same time the shock-resistance of the core is maintained. But what is frequently overlooked is that carburized cases added unintentionally can be detrimental to service life.

Laboratory study of failed tools has shown this type of trouble often happens. For example: Rivet sets, failing from brittleness after short service, were found to have a carburized case; coining dies failed by splitting, due to a deep carburized case (0.030 in.); an extrusion punch shattered, due to an excessive carburized case (0.040 in.), containing 3.34 pct carbon.

Unintentional carburized cases commonly result from heat-treatment operations where there is improper control of atmosphere, such as "inert" packing material, "neutral" atmosphere in furnace, and "neutral" salt bath. All of these, of course, are actually carburizing.

The cure for this type of trouble is simple — don't put on a carburized case. Or if you do, be sure to grind it off later. On most tools the required dimensions will not permit grinding off an excessive case. So the practical solution is proper control of the heat-treatment.

High-Speed Tool Steel Cuts 35 Teeth in Bronze Worm Gear

This tangential cutter, fitted with an insert of Bethlehem 66 High-Speed Tool Steel, is shown cutting a tooth on a bronze worm gear. The gear is 74 in. in diameter and is 3-1/16 in. deep. It has 35 teeth, having a circular pitch of 6.25 in. With its excellent red-hardness, balanced abrasion and shock-resistance, Bethlehem 66 High-Speed is an ideal steel for difficult cutting jobs.

The Inside Story of Lindberg's

An open letter to industrialists, anywhere!

For the last eight years, Lindberg has been steadily developing a strong international market for industrial heating equipment. This successful effort has attracted considerable interest among industrialists both in America and abroad.

A good many of these people have evidenced this interest by wanting to know more about how we developed this operation and the results we have had from it.

This International issue of Metal Progress seems to us to provide a good forum to answer publicly the most frequently asked of these questions.

You will, we believe, be interested in these answers. And we'd be less than human if we didn't hope that these will offer sound evidence that, when industrial heating equipment is needed anywhere in the world, you can best look to Lindberg.

Cary H. Stevenson

Cary H. Stevenson
Vice President
Lindberg Engineering Co.

If your plant, wherever it may be, uses industrial heating equipment, the facts about Lindberg's international marketing operation will interest you. The following questions and answers briefly explain the basic whys and hows of this successful program.

1. Why did Lindberg decide to go after an international market?

In 1946 Lindberg recognized that Europe, along with America, would be a major supplier to the metallurgical industry of the free world. Unlike some business people, we had complete faith in the rapid economic recovery of European industry. Therefore, it seemed sound to us to initiate a long range program for the development of manufacturing facilities in Europe.

2. How did Lindberg go about developing this program?

In 1946 we established a licensing arrangement with the Electric Furnace Co., Ltd., in England. Under this, furnaces designed by Lindberg were made by the licensee to exact Lindberg specifications. In 1947 a similar agreement was made with the Etablissements Jean Aubé in France. In 1951 Lindberg Italiana, in association with a group of Italian industrialists, was set up in Milan, Italy, under joint Lindberg and Italian control. In 1953, EFCO-Lindberg, Ltd., was established in Canada, under joint control of Electric Furnace Co., Ltd.,

LINDBERG MANUFACTURES:

Heat Treating Furnaces • High Frequency Heating • Laboratory Equipment • Fisher Melting Furnaces • Ceramic Kilns • Transformers

International Furnace Market

England, Williams & Wilson Ltd., Canada and Lindberg. In late 1954 a German company, Lindberg Industrie Ofenbau, was formed to be under joint control of a group of prominent German manufacturers and Lindberg.

3. What have been the results of the program?

We have sold and are continuing to sell Lindberg furnaces to users around the world. We foresee a volume in the near future that will either equal or surpass our volume in this country. In a few short years a world-wide acceptance has been achieved for Lindberg, and we believe we've also helped to popularize American industry abroad.

4. Has Lindberg sales volume abroad been with American firms or foreign firms?

We have done a lot of business with both types. Our foreign customers are many of the great manufacturing plants in Europe including Fiat, Necchi, Innocenti, Simca and Rolls Royce. American companies, as Ford in England, International Harvester abroad and Singer Sewing Machine plants all over the world, are also users of Lindberg furnaces. Hundreds of smaller plants throughout the world, both foreign and American, are Lindberg customers.

5. What advantages does this Lindberg operation offer potential customers?

Complete integration of licensed and associated-control companies assures the speedy availability of Lindberg equipment built to exact specifications anywhere in the world. Cost quotations can be made in various currencies: dollars, pounds, francs, lira, etc., enabling the customer to purchase Lindberg equipment with his most available and most economical funds.

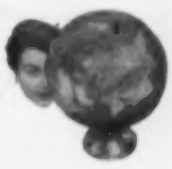
6. What advantages has this program provided Lindberg?

Obviously, the increased volume has been profitable to us. It has helped strengthen Lindberg engineering and laboratory facilities both here and abroad. More important, we now share in the latest developments in metallurgical processes and equipment created by engineering brains of Europe.

7. How does a prospective overseas customer for Lindberg equipment go about getting it?

That's easy. Either get in touch with our home office or any one of the companies shown below. Wherever you go you will be certain of getting competent engineering guidance and equipment of standard Lindberg quality.

The Electric Furnace Company, Ltd., Weybridge, Surrey, England
Lindberg Italiana, Milan, Italy
Etablissements Jean Aubé, Paris, France
EFCO-Lindberg, Ltd., Montreal, Canada
Lindberg Industrie Ofenbau, Gross Auheim, Germany



LINDBERG ENGINEERING COMPANY
2448 West Hubbard St., Chicago 12, Illinois, U. S. A.

Air and Hydraulic Cylinders

Los Angeles Plant: 11937 Regentview Ave. at Downey, California

Associate Company: Lindberg Industrial Corporation (Field-erected Equipment), 2321 West Hubbard Street, Chicago 12, Illinois

Whatever your furnace needs for control—

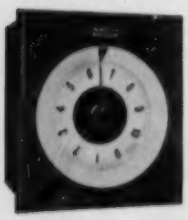
There's good reason why more heat-treating furnaces everywhere are controlled by Brown instruments. First, of course, is performance . . . sensitive, precise control that meets the most exacting requirements of modern heat-treating techniques. And equally important is versatility. In this varied line of instrumentation you'll find just about everything a furnace could possibly need in the way of control.

Just check through the requirements of your specific heat-treating problem . . . then look through this group of instruments and accessories:

Choose *ElectroniK* Strip Chart Controllers for detailed, long-term records . . . and a selection of control forms including electric systems of the contact, position-proportioning (*Electr-O-Line*) and time-proportioning (*Electr-O-Pulse*) types; and pneumatic control from two-position to full proportional-plus-reset-plus-rate action.

Choose *ElectroniK* Circular Chart Controllers for ease of scale reading . . . convenient daily charts; in a full range of electric and pneumatic control forms.

Choose *ElectroniK* Circular Scale Controllers where you want readability and control check at extreme distance . . . without need for a record. Supplied with all contact and proportional types of electric control.



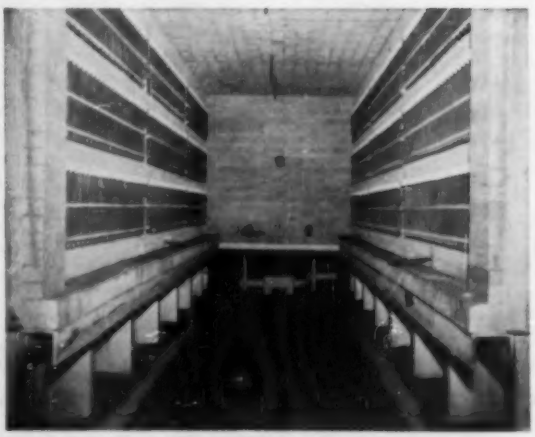
Choose *Pyr-O-Vane* Controllers where you don't need a record but do need precise vane type snap action electric control by a millivoltmeter instrument.

Choose *Protect-O-Vane* Controllers for simple, dependable excess temperature cut-off protection.

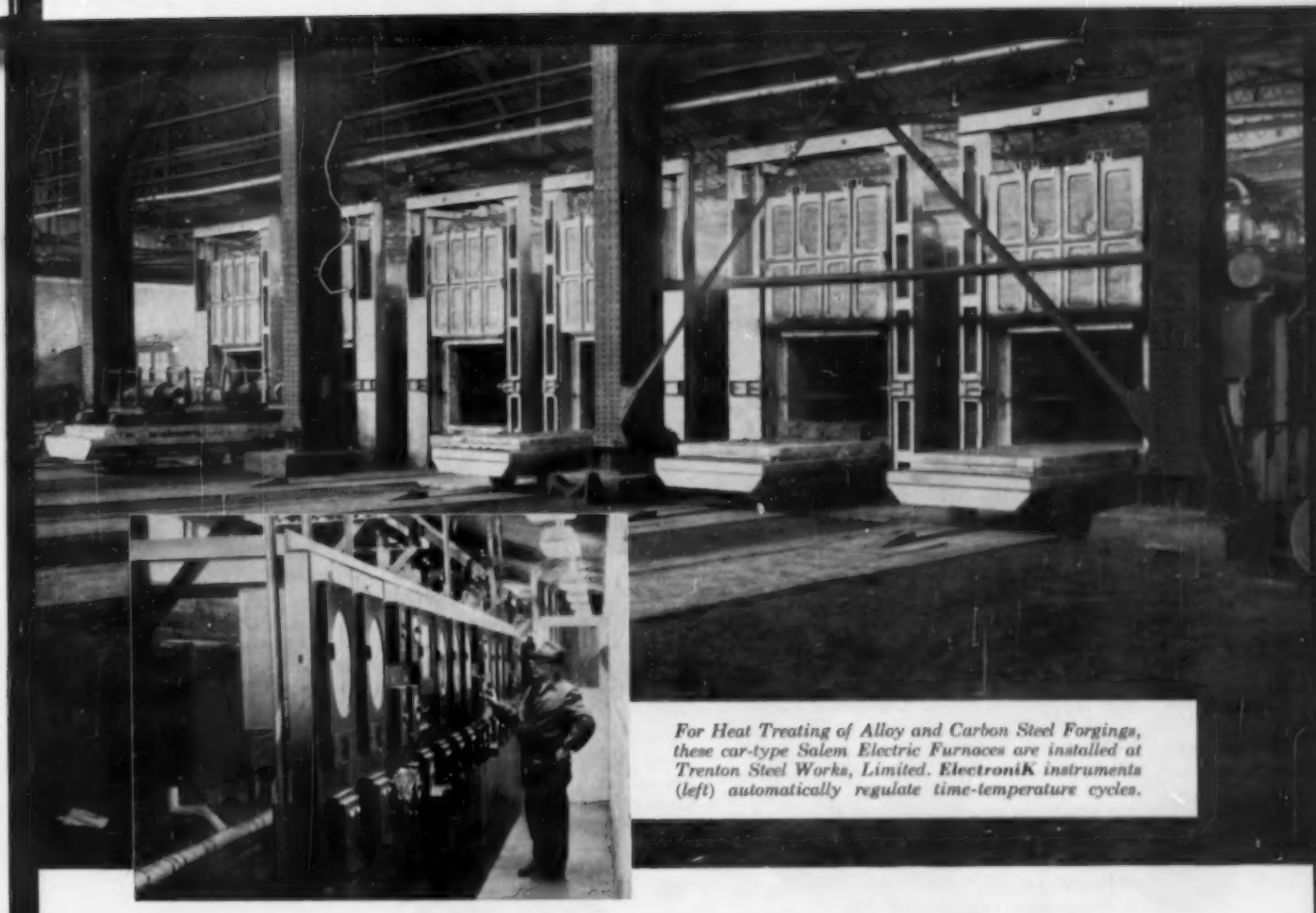
• • •

And for all your pyrometer supplies, investigate the HSM Plan—the convenient way to buy the best in supplies on a schedule custom-fitted to your plant . . . at advantageous discount schedules.

Big forgings get accurate Heat Treatment . . . *through*



*Thermocouples projecting into the interior of the furnace are connected to control instruments and to multi-point **ElectroniK** instrument that monitors all six furnaces.*



*For Heat Treating of Alloy and Carbon Steel Forgings, these car-type Salem Electric Furnaces are installed at Trenton Steel Works, Limited. **ElectroniK** instruments (left) automatically regulate time-temperature cycles.*

automatic time-cycle control

MODERN METHODS of automatic control, using *ElectroniK* instrumentation, are making heat-treating more automatic and more precise than ever. Look at what is being accomplished at the Trenton Steel Works, Ltd., plant at New Glasgow, Nova Scotia, as a typical example. Here a battery of six electrically heated, car-type furnaces manufactured by Salem Engineering, Ltd., are used for heat treating large carbon and alloy steel forgings. Without need for constant attention by operators, *ElectroniK* Program Controllers automatically conduct the furnaces through complete temperature cycles—bringing the forging through predetermined rise, soak and cooling periods with a precision that would be impractical for human control to accomplish.

The furnaces are multi-zone, with a separate *ElectroniK* Controller for each zone. As an overall safety measure, a multi-record *ElectroniK* instrument records temperatures of six selected points in each furnace and operates an alarm if any exceeds a preset maximum temperature.

The improvements in production quality and economy that *ElectroniK* control makes possible are readily applicable to any heat-treating furnace—large or small—electric or fuel-fired. And to assure continuity of performance, Honeywell offers the facilities of a nation-wide service organization to give prompt attention to routine or emergency requirements.

Your nearby Honeywell sales engineer will be glad to discuss your specific heat-treating control problems . . . and he's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.

● **REFERENCE DATA: Write for Catalog 1531, "ElectroniK Controllers" and for Catalog 54-1, "Furnace and Oven Controls."**

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS
First in Controls

5-Way Profit

Typical parts inspected at high speed, in high volume, with Magnaglo at Peoria Malleable Casting Company.

Another case study of money-saving casting inspection with **MAGNAFLUX***

1. **Eliminates rejecting finished parts because of cracks**
2. **Prevents processing of defective parts**
3. **Increases *salable* volume by 5%**
4. **Replaces visual inspecting with ¼ the manpower**
5. **Reduces inspection time from 8¾ to 1¾ man-hours per ton of parts**

At Peoria Malleable Casting Company, with their old visual inspection system, 5% defective castings were processed through annealing and grinding and later scrapped. Worse, the cause of the defects went undetected. This meant continued scrapping, greater time loss, higher production costs. Peoria Malleable produces rough castings, and finishes many, for tractor housings, clutch and brake pedals, etc.

The problem was solved by "Correctioneering"—using a Magnaflux-Magnaglo* unit to detect defects early, in *rough* castings. Time is no longer wasted on defective materials and this early detection makes the cause of defects much easier to spot and correct. Since 1952, when the Magnaglo unit was installed, there have been almost NO CUSTOMER RETURNS for cracks. Customer good will is insured.

With the Magnaglo unit, *anyone* can inspect with 100% accuracy. One man now takes 1¾ hours to inspect a ton of castings, whereas it formerly would have taken four men a total of about 8¾ man-hours.

Whether you make castings, carburetors, cranes—or just about anything else—ask for our booklet to study profitable savings for you. Write today for "FINDING THE 'HOW AND WHERE' OF LOWER PRODUCTION COSTS."

MAGNAFLUX DETECTS DEFECTS

*Magnaflux and Magnaglo are Registered Trademark of Magnaflux Corporation

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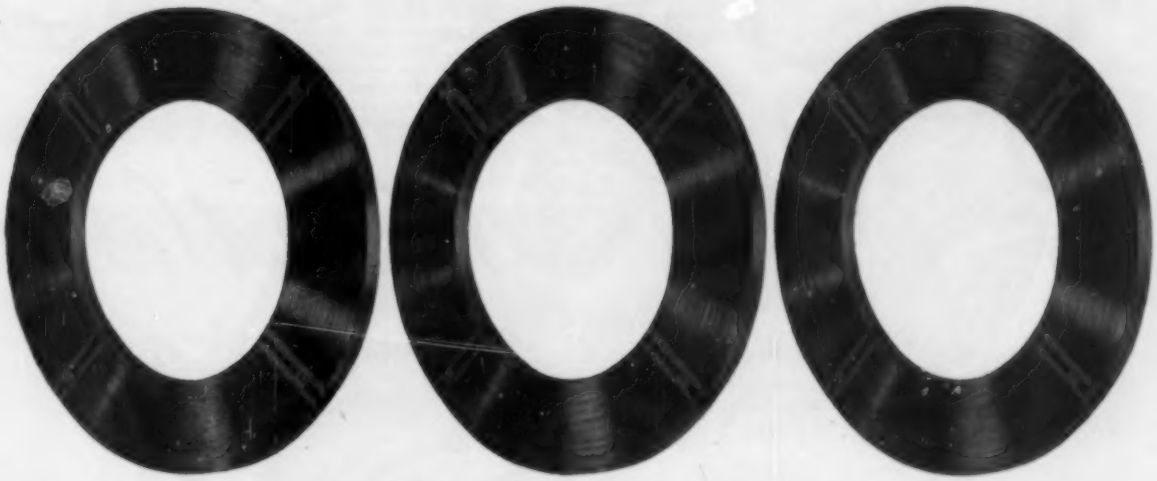
Ease and simplicity of operation of Magnaglo unit gives 100% inspection accuracy



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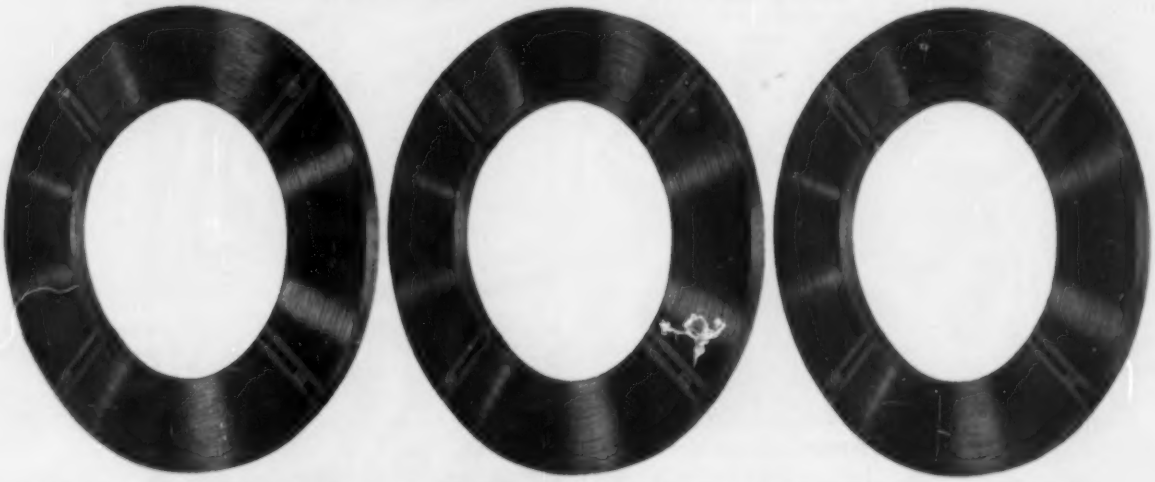


full range of COLD ROLLED specialty steels

Look to Crucible for highest quality cold rolled specialty steels. You'll find a wide assortment of alloy strip and carbon spring steels . . . in many analyses, sizes, shapes and finishes.

Crucible, the nation's leading producer of *special purpose steels*, controls steel production from ore to finished product. And special Crucible-patented machines bring you cold rolled steels with *finer* finish . . . better edges . . . closer than standard tolerances.

When you have a cold rolled specialty steel application, call Crucible in during the *planning* stage. Crucible engineers can help you develop the specification . . . and knowing the end use for the steel, will prescription-make it to suit your needs—in coils or cut to your particular length requirements. *Crucible Steel Company of America, Henry W. Oliver Building, Pittsburgh 30, Pa.*

CRUCIBLE first name in special purpose steels

Crucible Steel Company of America

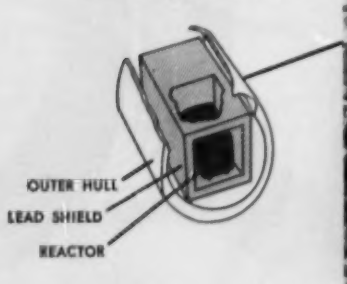
"... Build thee more stately mansions, Oh my soul,
As the swift seasons roll!
Leave thy low-vaulted past!
Let each new temple, nobler than the last,
Shut thee from heaven with a dome more vast,
Till thou at length art free,
Leaving thine outgrown shell by life's unresting sea!"

"The Chambered Nautilus"

by Oliver Wendell Holmes

right: Launching of the world's first atomic-powered submarine, the *USS Nautilus*, January 22, 1954. *Courtesy General Dynamics Corp.*

below: Schematic drawing of lead chamber and relative position in submarine.



A LEAD CHAMBER encloses the *USS Nautilus'* heart. Beginning with the *USS Holland*—the world's first submarine – all such vessels derived the power needed for sub-surface travel from storage batteries. The chief component of these batteries, about 60% by weight, is lead – the imperishable metal. In the recently launched *USS Nautilus*, the deadliest submarine of all time, lead, besides its conventional function in storage batteries, has this additional and very vital job: To shield the crew from the dangerous rays emitted by the *Nautilus'* heart – the nuclear power plant. Basically, the problem of protection from these rays is the same as that required for protection from X-rays and radium. For the latter purposes, the value of lead as a protective shield has long been recognized. The impermeability of the shielding material to penetration of rays is a function of its density. Lead is the densest of any commonly available metal. At 20°C lead's density is 11.35, as against 6 to 9 for ferrous metals. For a given degree of shielding, lead is the least bulky material – and has the most practical balance between ray-stopping power and cost. Hence, where space is at a premium, and utmost radiation protection is paramount, lead is usually specified. No metal is easier to work than lead – a fact with obvious cost and "on site" fabrication implications.

These advantageous properties, together with the metal's availability and relatively low cost, are certain to widen the application of lead in the growing field of harnessing atomic energy for industrial use. According to Dr. Marvin Fox, chairman, reactor department, Brookhaven National Laboratories, one of the major uses of lead, and one that promises to be still greater, is in the manufacture of shipping and handling containers for radioisotopes and in laboratories handling these materials.

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DRIOX liquid oxygen storage units such as this hold as much as 12,250 oxygen cylinders—enough for 82 hours of capacity operation of a large steel plant.

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Mold reaction resulting from improperly conditioned sand is the cause of many defective castings.

Low flowability of sand may cause a ram-off, which will result in a shift. Excessive moisture in sand may cause boiling of the metal against the mold surface and where steam bubbles fail to find their way through the surface of the casting, before the metal solidifies, defects such as shown are the result.

Weak sand, that is, sand with insufficient bond or with improperly distributed bond material causes sand wash and cutting, leaving rough lumps at some points on the casting and angular holes at other points. These are but a few of the problems caused by poor sand practice.

Lavin's metallurgical staff is always ready to assist the foundryman in finding the solution of any routine or special casting problem. Our chemical and research laboratories are available to you at no cost or obligation.

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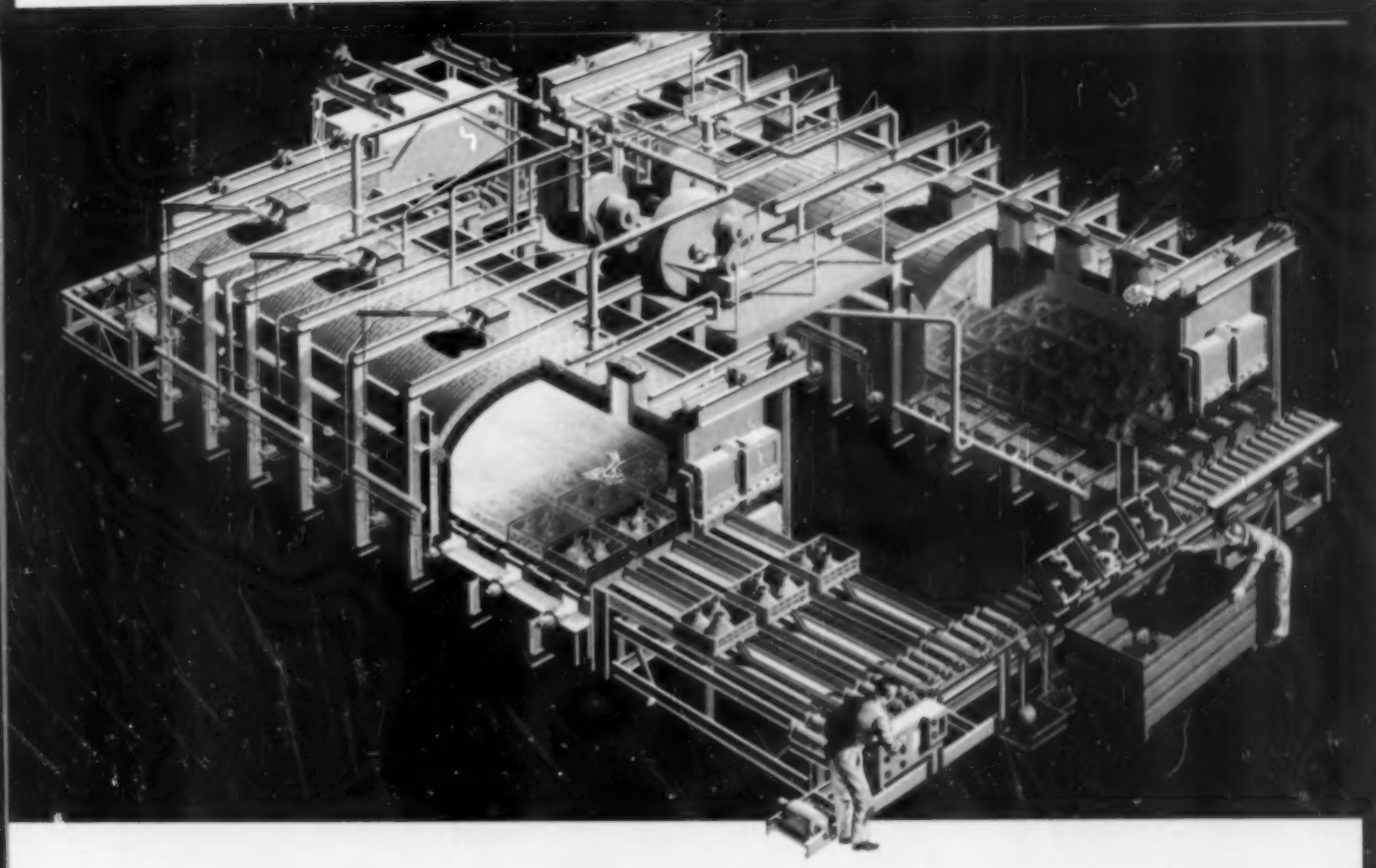

You get automatic, precise heat treatment plus high production with this Salem-Brosius furnace

You speed production—control heat treating cycles to close limits—achieve specified metallurgical and physical properties in forged parts with this Salem-Brosius furnace.

This is possible because time, temperature and material movement are automatically controlled to provide precise cycle annealing practice. Rugged construction and simplified design give you efficient operation with low maintenance.

Here is a typical cycle. Forged alloy steel automotive parts, such as clutch plates and drive pinions, are loaded into three trays and positioned in front of the furnace pusher on the left. The furnace takes over.

The trays move automatically into the heat and soak chamber where the parts are heated to 1700°F. and held at that temperature for a timed interval. Then they move to the next section and are control-cooled to 1200°F. at which moment they move to the final zone and are control-cooled to 500°F. At this time the trays are ejected to a transfer table from which they are automatically emptied into tote boxes.

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This furnace is typical of the efficient heat treating and heating furnaces designed and built by Salem-Brosius to increase your production and reduce your unit costs. The skill and experience of Salem-Brosius engineers recently were augmented by the acquisition of the George J. Hagan Company so that now you get the benefit of the combined abilities of both organizations to design, engineer and build fine furnaces when you specify Salem-Brosius. Write to us!

SALEM-BROSIUS, INC.

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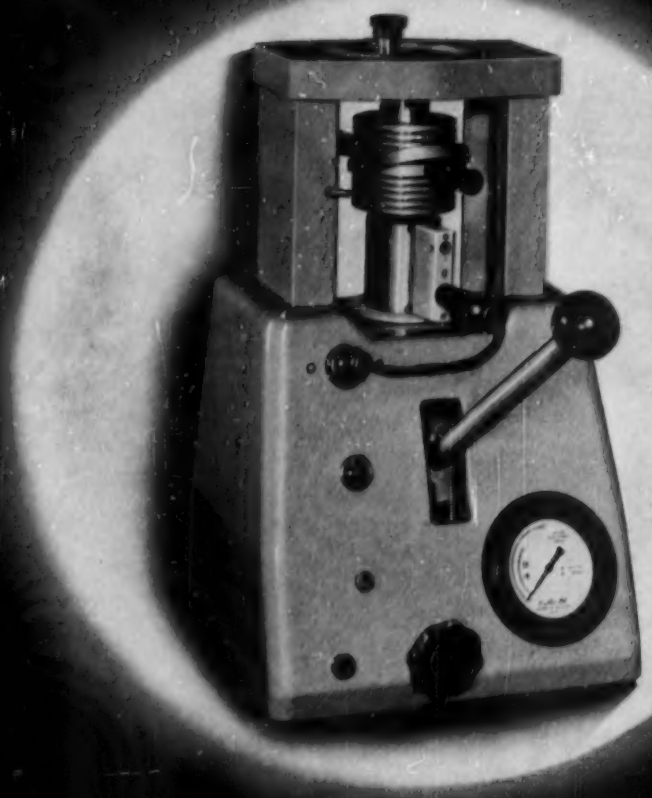

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Latest design in Press equipment for processing Bakelite and Transoptic mounted micro samples is now offered to the Metallographic Laboratory.

This new Press provides practical center ejection of 1" or 1¼" mounted specimens. The heating unit is controlled by thermostat and need not be removed from the press structure. The cooling block rigidly encloses and holds the mold assembly.

Minimum amount of handling molding accessories, speed and ease of sample ejection, practical and economical operation of molding tools were paramount in the development of this new AB Centermet Press.

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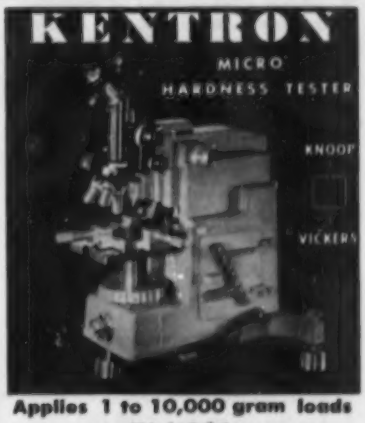

Applies 1 to 10,000 gram loads
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LAB-HYAM

Protective Atmosphere H_2N_2
Less Expensive-More Convenient
LAB size for LAB work

Protected bright annealing is now here for test and pilot runs of electric metals, stainless steels, copper or silver brazing; for sintering or reducing powder metals and for bright tempering of any ferrous or non-ferrous metal or alloy. How about atmosphere?

At 1900°F. from raw ammonia gas LAB-HYAM catalyst chamber produces a 75% hydrogen—25% nitrogen mixture from 99.9% dissociated ammonia, delivering protective atmosphere at 5 to 35 C.F.H. through needle valve.

Ask for Bulletin L-H for more information regarding this new laboratory size Dissociated Ammonia Generator.

LAB-HYAM H_2N_2 GENERATOR

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Demagnetizing
or Sorting
PROBLEMS?
SOLVED with

MAGNETIC ANALYSIS MULTI-METHOD EQUIPMENT

Electronic Equipment for non-destructive production inspection of steel bars, wire rod, and tubing for mechanical faults, variations in composition and physical properties. Average inspection speed 120 ft. per minute.

Over 50 steel mills and fabricators are now using this equipment.

MAGNETIC ANALYSIS DEMAGNETIZERS

Electrical Equipment for rapid and efficient demagnetizing of steel bars and tubing. When used with Magnetic Analysis Multi-Method Equipment, inspection and demagnetizing can be done in a single operation.

MAGNETIC ANALYSIS COMPARATORS AND METAL TESTERS

Electronic instruments for production sorting both ferrous and non-ferrous materials and parts for variation in composition, structure and thickness of sheet and plating.

MAGNETIC ANALYSIS MAGNETISM DETECTORS

Inexpensive pocket meters for indicating residual magnetism in ferrous materials and parts.

For Details Write: "THE TEST TELLS"
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FOR *Ultra Sensitive*
STIFFNESS TESTING
it's the
TABER
STIFFNESS
TESTER

New Taber V-5 Stiffness Tester is now available with 8 test ranges instead of 6. Now flexural rigidity of very thin materials such as metal foil can also be determined with SR 150-14 attachment. Recognized as the official test of initial and basic stiffness of sheet and wire, the V-5 has standardized test length, angle of deflection, and rate of loading to assure coordination between laboratories. Direct dial readings.

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For Industrial and Decorative Electroplating

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JAckson 1-4200

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USE SWIFT BLACK!
For efficient metal cleaning
USE SWIFT METAL CLEANING COMPOUNDS!
For certain rust prevention
USE SWIFT RUST PREVENTATIVES!
For heat treating
USE SWIFT SALT BATH!
For quenching
USE SWIFT QUENCHING OILS!

Send TODAY for descriptive literature and technical data sheets.

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for rapid, accurate, non-destructive
THICKNESS MEASUREMENTS from oneside and accelerated METAL CLEANING

VIDIGAGE Automatic Thickness Tester
Direct-Reading 21" Cathode-Ray Tube. Infinite Ranges 2:1, as selected, between 0.015" and 6" of steel or equivalent. Accuracy 0.1%—1.0% according to use.

AUDIGAGE® Portable Thickness Testers
Battery-Operated. Ranges 0.020"-4" and 0.060"-12" of steel or equivalent

SONOGEN Ultrasonic-Power Generator
for Metal Cleaning and other industrial uses.

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Grade "B"
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Eliminates . . .
Rust
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Toxicity
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Degreasing
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CIRCO Metal Cleaning Equipment CUTS costs

SINCE 1923

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CIRCO VAPOR DEGREASERS—large or small—automatic or manual operation

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CIRCO-SONIC DEGREASERS — newest development—cleaning by *ultrasonic* vibration

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FREE! Write for 32-page CIRCO Degreasing Manual

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- Steam Jets • Chain
- Mechanical Bar, Tube and Coil Picklers

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for all industrial requirements

for de-greasing — pickling
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materials handling
small-parts storage

of any size and shape — any ductile metal

by THE C. O.

WIRE PRODUCTS JELLIFF SINCE - 1880

JELLIFF MFG. CORP.

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Du-Lite FINISHED

The Marlin Firearms Co., "Famous for Fine Guns since 1870", has long depended on Du-Lite black oxide for an attractive finish that will be dimensionally stable throughout the life of the gun.

The Du-Lite process provides intricate precision parts with a durable, rust-resistant black oxide finish. And since Du-Lite penetrates the metal, all crevices and knurls are protected without affecting dimensions or fit.

If your target is durable, attractive, economical finishing, you'll want to know more about Du-Lite black oxide.

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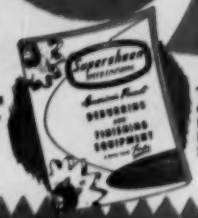

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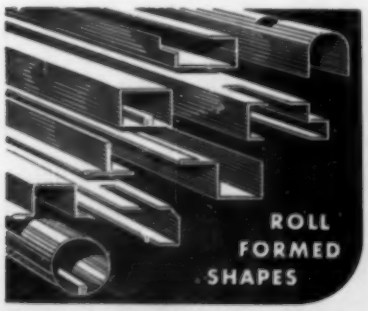

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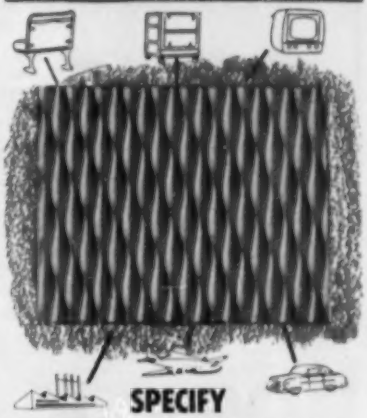

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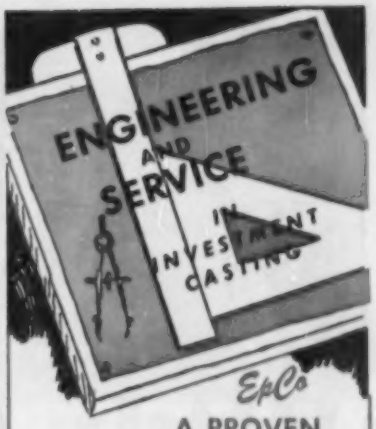

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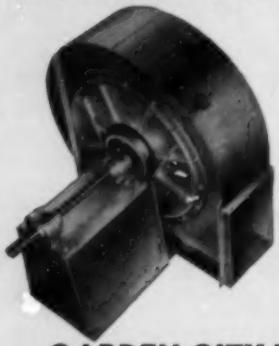

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fast . . . inexpensive way to expand your plant facilities. Choose from 27 Models.

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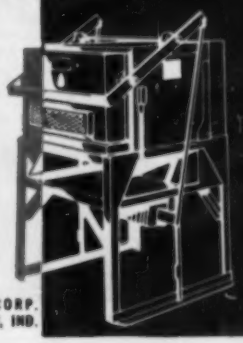

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AUTOMATICALLY

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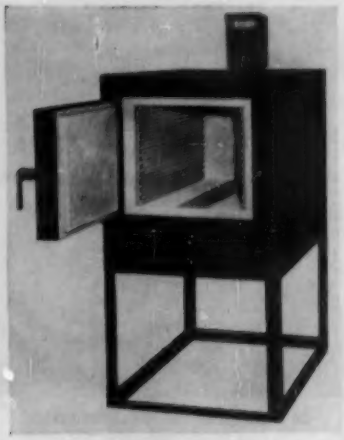

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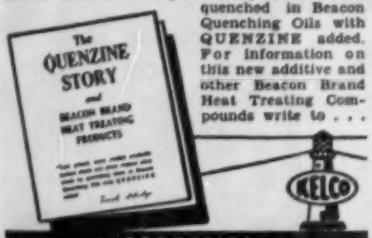

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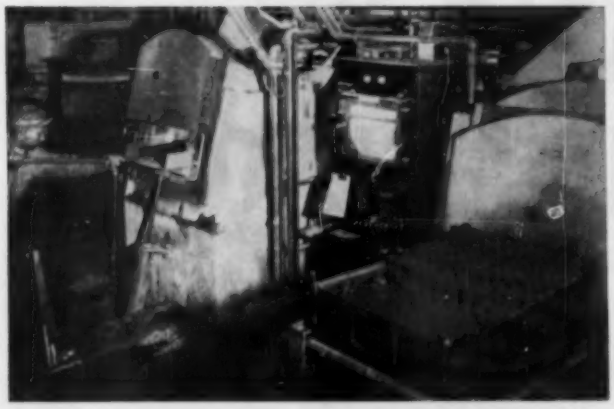

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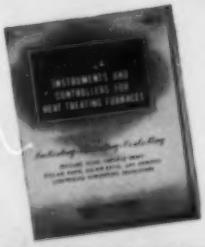

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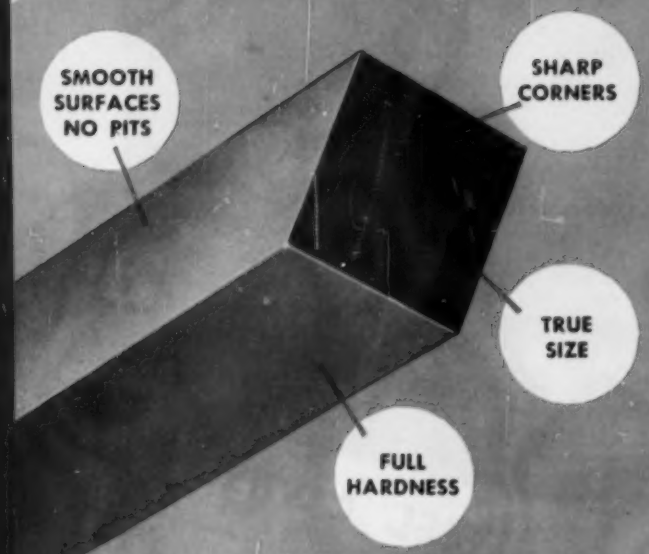

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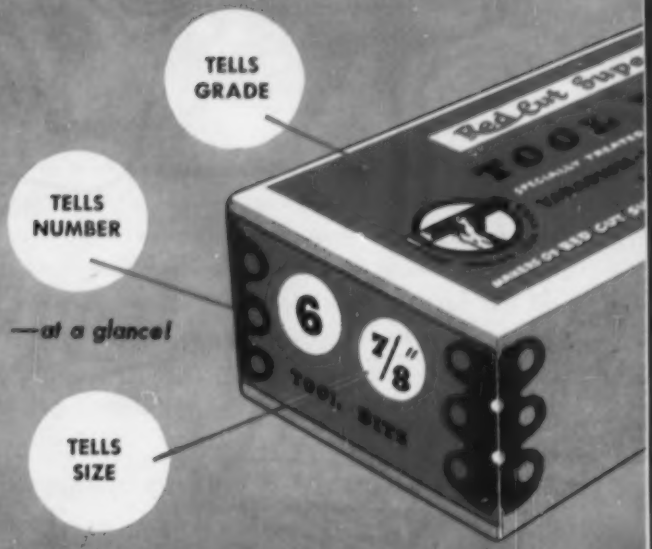

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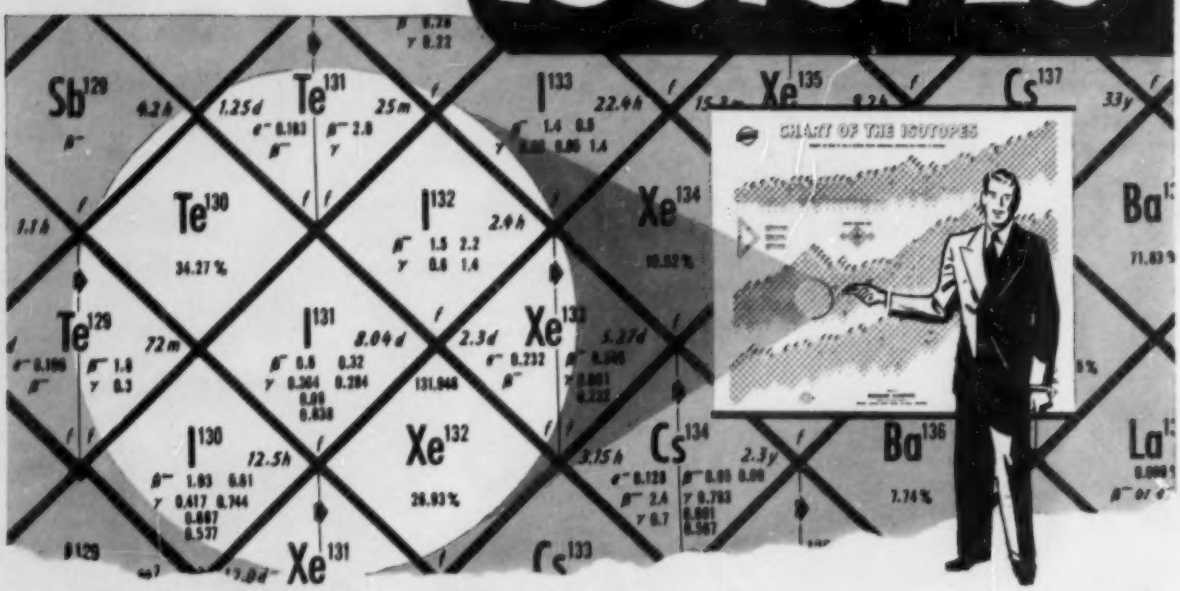
All the useful information about ISOTOPES



contained in Harshaw Scientific's COLOR CODED (wall) CHART of the ISOTOPES*

SIZE
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Invaluable as ready reference for teaching or those working with or considering Isotopes

Judged by many as the most useful wall chart since the periodic chart of the atoms, the Harshaw Chart of the Isotopes makes available in easy to read and easy to use form ALL the useful information about ISOTOPES.

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THE CHART PROVIDES THE FOLLOWING INFORMATION:

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- Atomic Weight, 1952 Revision
- Thermal Neutron Cross Section
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- Radioisotope half-life
- Modes of Radioactive Decay
- Radiation Energies in Million electron volts
- Isomeric States
- Isomeric Transitions
- Nuclear Transmutation Code
- Percentage Abundance of Naturally Occurring Isotopes
- Fission Data (thermal fission of U^{235})
- Lithographed in 8 Colors Plus Black and Gray

Corrected to February 1, 1953

Compiled and Edited by JOHN R. BRADFORD, Ph.D. Director Radioisotopes Laboratory, Case Institute of Technology. **International copyright*

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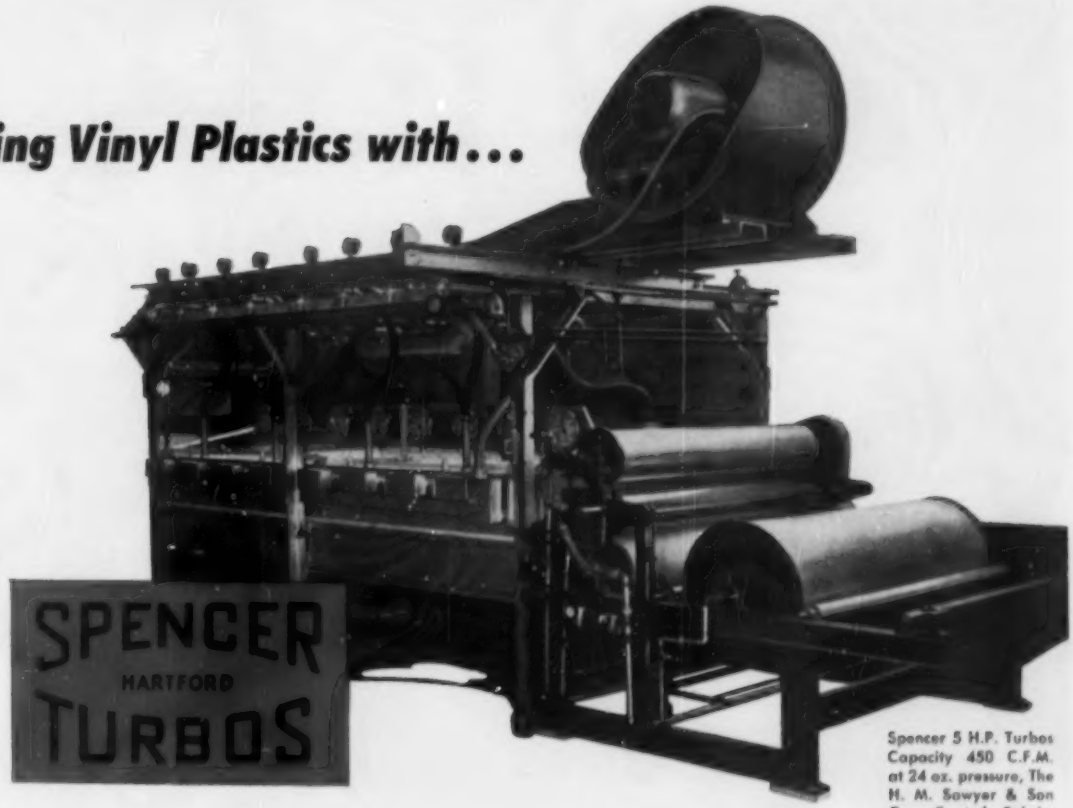

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Information on Spencer Turbos is given in Bulletin No. 126 and special applications in Bulletin No. 107.

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Yoloy reduces body weight, increases payload

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Above: Trucks with Perfection Special Contractors' Type Body —all fabricated from Yoloy Steel.

YOLOY IS AVAILABLE in sheets, plates, strip, pipe, mechanical tubing, bars, shapes and cold finished bars.

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"The physical properties of Yoloy are such that lighter gauges used in the construction of dump bodies result in considerable weight reduction and thereby provide increased payloads. Yoloy's corrosion resisting qualities provide the additional advantage of lending longer life to the equipment".

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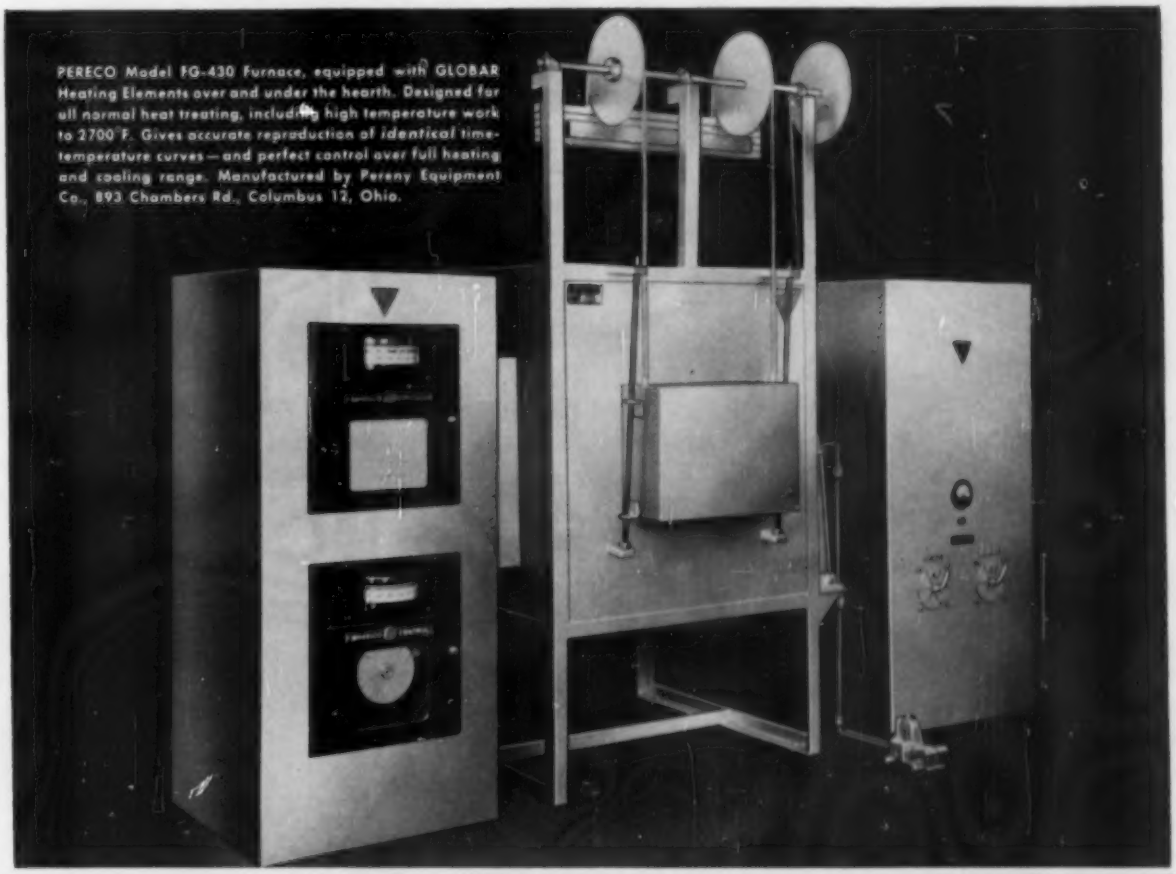

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PERENY selects GLOBAR® Heating Elements

. . . for this High Temperature Heat Treating Furnace

GLOBAR Silicon Carbide Heating Elements were chosen by Pereny for this modern, accurate heat treating furnace because they convert electrical energy into clean, safe, uniform, dependable heat.

Pereny is one of 40 leading furnace manufacturers who specify GLOBAR Heating Elements in many of their electric furnaces. GLOBAR'S engineering staff works closely with these manufacturers to give *you* the most modern, efficient, and economical equipment for industrial heating processes—whether it be heat treating brazing, annealing, forging or sintering.

Any problem you may have in the medium and high temperature range of industrial heating will be tackled vigorously by our engineers . . . without obligation to you. The solutions they propose often result in much lower overall operating costs—even when electricity costs more than other fuels! Write to the GLOBAR Division, Dept. MP 87-42, The Carborundum Company, Niagara Falls, N. Y.

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from VACUUM MELTING–
improved alloys with exceptional properties

WHAT ARE VACUUM-MELTED METALS?

Vacuum-melted metals are a familiar family of alloys with new, improved characteristics. For during high-vacuum melting, gaseous impurities are literally sucked from the molten metal. The result is cleaner, purer metals with desirable properties not previously attainable . . . in, for example, superalloys, bearing steels, high-strength steels, electronic metals, or magnetic alloys.

WHAT ARE THEIR ADVANTAGES?

Many characteristics of a specific alloy can be improved by vacuum melting and casting . . . for impurities that limit an alloy's potential are removed. Tensile and impact strength, stress rupture strength at elevated temperatures, and fatigue life can all be substantially improved . . . and creep and brittleness minimized by vacuum melting.

HOW CAN I BEST USE THESE IMPROVED ALLOYS?

Frankly, vacuum-melted metals are so new that many applications for them have not yet been explored. But where they have been used, they've *proved* their effectiveness in improved performance. Superalloy jet engine turbine blades, for example, have given more than *twice* the performance life of blades made of conventional air-melted alloys. And ball bearing rejects dropped from 50% to 3% when vacuum melted steels were used.

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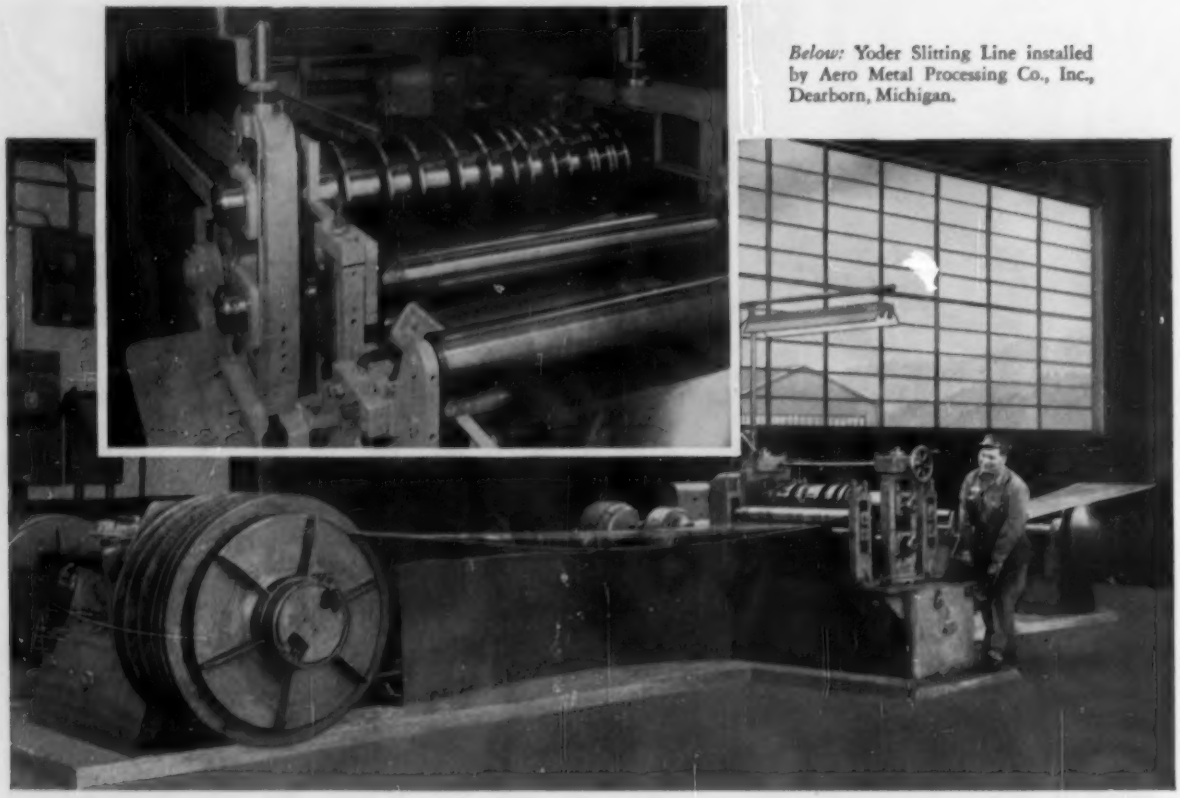

Below: Yoder Slitting Line installed by Aero Metal Processing Co., Inc., Dearborn, Michigan.

When is a Slitting Line Profitable?

● Many variables are to be considered in determining where and when a slitting line becomes a good investment. Also of what size, type, speed it should be, and other special features required to make it most profitable under any given set of conditions. Without obligation, a Yoder representative will call upon request and discuss such details with you.

The Yoder Slitter Book deals extensively with basic considerations in the choice and operation of slitting lines; points out, for instance, how and where a relatively small, inexpensive installation may be more economical than a larger, faster, and costlier one. (Yoder makes all types). Time studies show how coil size, strip gauge, slitter speed, coil handling and banding time affect cycle time and cost per ton.

The book is useful not only to present operators of slitting lines but to producers, users and distributors of strip and sheet metal who may be considering installing slitting equipment. A copy is yours for the asking.

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- ★ GANG SLITTING LINES for Coils and Sheets
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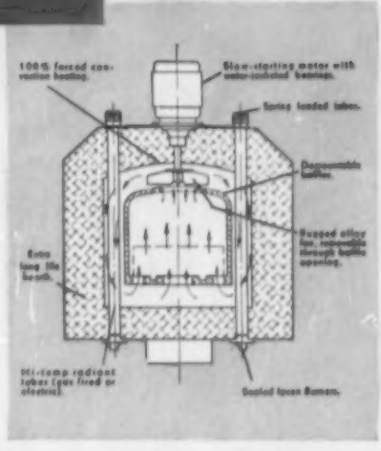
GREATER EFFICIENCY with Ipsen New 100% FORCED CONVECTION UNITS

▲ *New Ipsen 400 Lb./Hr. Automatic Heat Treating Unit equipped for martempering. Straight-through operation from heat through quench, or cooling, eliminates loading delays.*

▶ *Ipsen's new radiant tube and 100% forced convection heating design. Spring-loaded tubes seal automatically. Controlled atmosphere throughout assures bright, clean, scale-free work.*


100% forced convection heating.
Slow-starting motor with water-cooled bearings.
Spring loaded tubes.
Demountable baffles.
Rugged alloy fan, removable through baffle opening.
Extra long life hearth.
Hi-temp radiant tubes (gas fired or electric).
Sealed Ipsen Burners.

Ipsen controlled atmosphere heat treating units are designed with 100% forced convection heating to provide greater efficiency. Built for temperatures up to 1850° F., they can profitably handle a wide range of work, both in small lots and in production runs.

These are some of Ipsen's outstanding design features which will give you greater efficiency in processing:

1 **100% Forced Convection Heating**—powerful alloy fan forces atmosphere around radiant tubes, under floor, and *through* the work. Provides faster heat recovery and uniform circulation. Fan is removable through baffle opening in hearth.

2 **Long Life, Radiant Tubes** — withstand high temperatures, assure long, trouble-free service. Light in weight, are easier to remove, cost 50% less to replace.

3 **New Sealed-in Silent Burners**—provide accurate flame control, fast temperature buildup, *complete* combustion and uniform temperature.

4 **Demountable Baffles** — assure complete circulation of atmospheres through the load and maintain uniform work temperature. Sectional-type construction permits easy replacement. Complete unit can be removed in ten minutes.

Send **Samples for Free Estimate**—find out how the new Ipsen Units can be applied to your job. Samples of your work will be run, procedures established in our new, modern lab, and cost estimates given without obligation.

Write **for New Literature**—illustrates new design features, gives complete specifications of various units.

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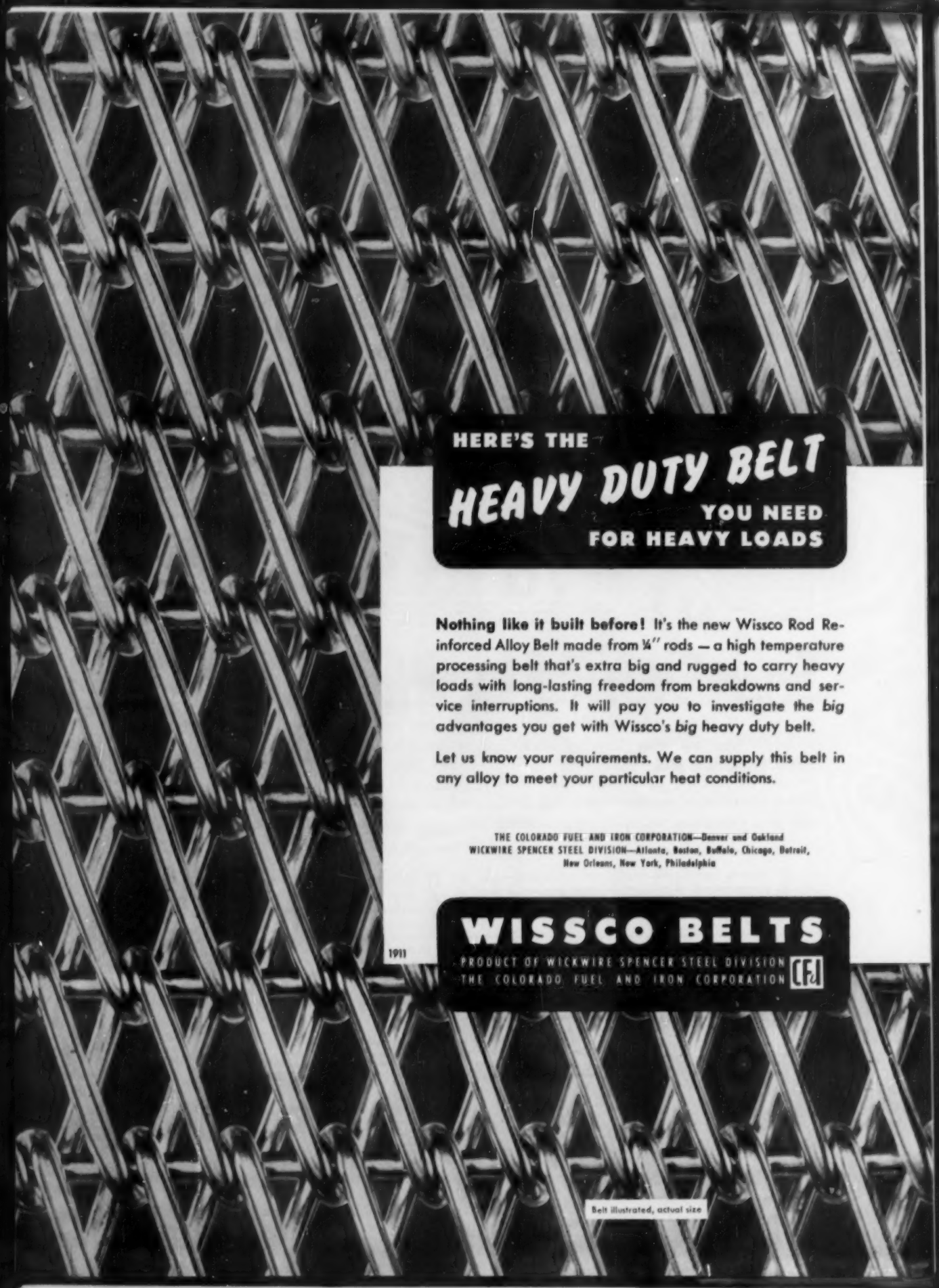
Universal Units for CARBONITRIDING • CARBURIZING • HARDENING • BRAZING • MARTEMPERING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The Park Neutra-gas Story:

No sludge, no de-carb in neutral salt baths rectified by Park's patented process!*

A patented development of Park's research laboratory, the Neutra-gas process efficiently and economically neutralizes chloride base salt baths . . . maintaining them free of de-carb in temperatures ranging from 1350°F. to 2300°F. The decarburizing oxides present are chemically converted back to chlorides by passing methyl chloride through the molten baths.

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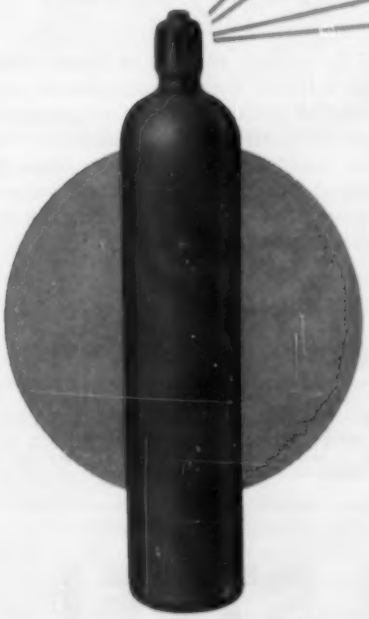
Complete details of the Neutra-gas process plus valuable information on neutral salt baths, their operations and uses, are described in a technical bulletin available to you by mailing the attached coupon.

* Truly neutral chemically. Alkalinity can be maintained at zero.

At Commercial Steel Treating Corp., in Detroit, salt bath furnaces are daily cleansed of all impurities. Rectifying gas is bubbled into Park Nu-Sal Neutral Salt molten at its operating temperature of 1500°F.

Even high-speed hardening baths up to 2300°F. are easily maintained neutral. At Commercial, both pre-heat and high heat are rectified daily to zero alkalinity. Rectification is at 1850°F. in the high heat, done either on idling time or when furnaces are being used for hardening high carbon, high chrome die steels. Salt is Park Pre-heat 117, and Park High Heat 175-S.



Methyl Chloride (CH_3Cl) is a liquefied gas, 99.98% pure (by weight).

Patent number—2474680—Neutra-gas Process license fee, $25.00 per year.

Third in a series of advertisements describing Park processes on the job.

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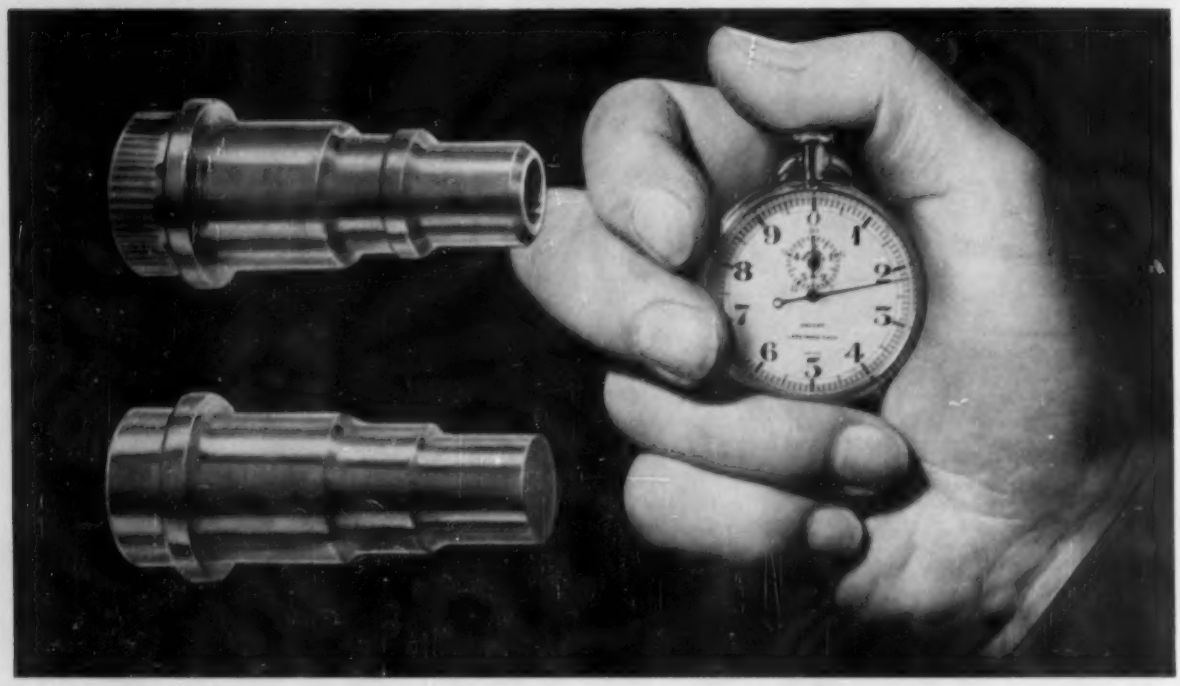

Finished 50% faster

Using Ledloy from Ryerson

By the time the B-1113 piece was finished, you'd be halfway through a second Ledloy piece. Such greater speeds and feeds are possible with Ledloy because Ledloy contains a *built-in lubricant* which substantially reduces the friction between the steel and the cutting tool.

That built-in lubricant is *lead*—so finely dispersed through this free-machining, open-hearth steel that you can't see it with a microscope. The addition of this small percentage (.15-.35) of lead has no effect on the mechanical properties of the steel EXCEPT to greatly increase machinability.

Ryerson Ledloy machines up to 50% faster than B-1113 . . . tool life is extended as much as 200% . . . and net savings of 25% and more are effected. And Ledloy machines to an unusually clean, smooth finish—case hardens effectively —and bends, crimps, swedges or rivets easily.

Ask your Ryerson representative for the facts about Ledloy or write us direct for engineering data. Ryerson was the first to stock Ledloy and today your nearby Ryerson plant carries the world's largest stocks of Ledloy rounds, squares and hexagons in a wide range of sizes for immediate shipment when you call.

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Metal Progress

Volume 67, No. 1
January 1955

This issue starts the 25th year of *Metal Progress's* life. That fact, we hope, is only a minor incident in its continual growth in usefulness to the metallurgical profession. This issue is also our third annual review of international progress in metallurgy. We believe it sets a new high in quality – as is only to be expected from the professional standing of the authors. So much good copy came from abroad that several articles about progress in this hemisphere were crowded out; they will form the nucleus of another special issue in 1955 reviewing American progress in metallurgy. All of us wish you a happy New Year!

E. E. Thum,
Editor-in-Chief

Pig Iron Made From Low-Grade Fine Ore and Noncoking Coal*

A complete pilot plant for making 40 tons of pig iron per day from low-grade granulated ore and noncoking fuel has produced about 8000 short tons of marketable iron in three campaigns. Experience indicates various factors, such as blast enrichment and velocity, charging methods, and amount of fines which can be tolerated in semicommercial operation.

PERHAPS it would be well at the outset to give readers of *Metal Progress* some brief notes on the project whose early operations are to be described. The project for erecting and studying a low-shaft furnace has been a joint undertaking of seven European countries, namely, Austria, Belgium, France, Greece, Holland, Italy, Luxembourg (to which should later be added the Battelle Memorial Institute of the U.S.A.). An international board of directors was appointed in April 1951 which immediately appointed a technical committee. A site was secured adjoining the blast furnace department of the Ougrée-Marihaye Co., served by trackage of the Belgium Nitrogen Co. Oxygen for blast enrichment was also available (95% pure) from the joint distribution system serving the nearby iron and steel plants of the Esperance-Longdoz, Cockerill, and Ougrée-Marihaye companies.

Ground was broken in July 1952 and the first experiments were performed on May 13, 1953 – that is, less than a year later. In a period of

*Staff paper from the International Committee for Research on the Low Shaft Furnace.

too much talk and too little action, here was indeed one fine example of useful international cooperation.

Operation and research were assigned to the Liège section of the Belgium National Center for Metallurgical Research. Staff and advice came from the nearby plants and from other Belgian, French, Italian and Luxembourg research workers, thereby continuing the international character of the project.

In western European countries the principal interest of the low-shaft furnace lies in the manufacture of liquid pig iron from raw materials which cannot be used in normal blast furnaces without interfering with their efficiency or which cannot even be treated in them under any circumstances. The Committee faced four requirements in approaching such a problem: First, the charge must be of fine material, not agglomerated or sintered, and contain some of substandard quality. Second, the reactions occurring while smelting this material in a low-shaft furnace must be studied. Third, these must be compared with a conventional blast furnace. Fourth, the program must be such that single variables can be studied, and sufficiently flexible so it can be changed as developments warrant.

The Plant at Ougrée

The initial program therefore can be outlined as follows: At the beginning the fuel would be metallurgical coke but of such small grain size it would be difficult to use in a blast furnace. Wherever possible, the tests should be oriented toward the consumption of a quality inferior to what could be used in a blast furnace – such as semicoke, fine coke, even uncoked coal.

Moreover, the ore treated would come from Lorraine or Luxembourg mines and should have a fine grain size distribution analogous to the fines going through 20-mm. (¾-in.) screens after crushing. As a general principle the charge should have an initial size between 10 and 20 mm. (+ ⅜ – ¾ in. approx.) and the tests should aim toward the increased use of particles less than 10 mm. (– ⅜ in.).

These conditions are thus quite different from those existing in other low furnaces, whether in the smelting of ferromanganese and ferrosilicon (where a charge of high permeability is assured by a high ratio of coke), or in the smelting of cast iron from agglomerated nodules of ore and fuel, or from sintered ore-flux mixtures.

Note also that in order to obtain results useful to industry and to avoid too excessive thermal losses, the international committee had decided that a furnace should be built of sufficient production capacity as to be in effect a pilot plant, capable of continuous operation, so that defects of design or inadequacies of constructional materials could be discovered and corrected – and also that the data on operation could be extrapolated to industrial scale without too much error. This set, as a limit, the hearth area at the tuyeres of 3 sq.m. (32.3 sq.ft.). As shown in the drawing, Fig. 1, an oval shape was adopted, since the conventional circular plan of iron blast furnaces would mean such a large diameter that we feared the blast could not penetrate to the center, in which case there would be a cold, inert zone at the axis. (Ideally, the cross section should be rectangular, like a water-jacketed copper blast furnace which needs merely be lengthened to increase its capacity; the oval form was a compromise into a shape which could readily resist the internal pressures and thermal stresses.) At any rate, it was believed – and experience so far confirms this belief – that fine granular charge must pass into the focus near the ends of the tuyeres. Otherwise it goes on, unreduced, into the hearth below, entering either the slag or contaminating the molten iron.

The furnace as built (Fig. 1) has a cylindrical shaft, 3 m. by 1.200 m. in area and 5.800 m. from hearth to top of burden (9 ft. 7 in. major axis, 3 ft. 11 in. minor axis, burden 19 ft. high). Charging is through two bell-bottomed closed hoppers, designed to be sufficiently tight so the furnace can be operated with high top-pressure, if desired.

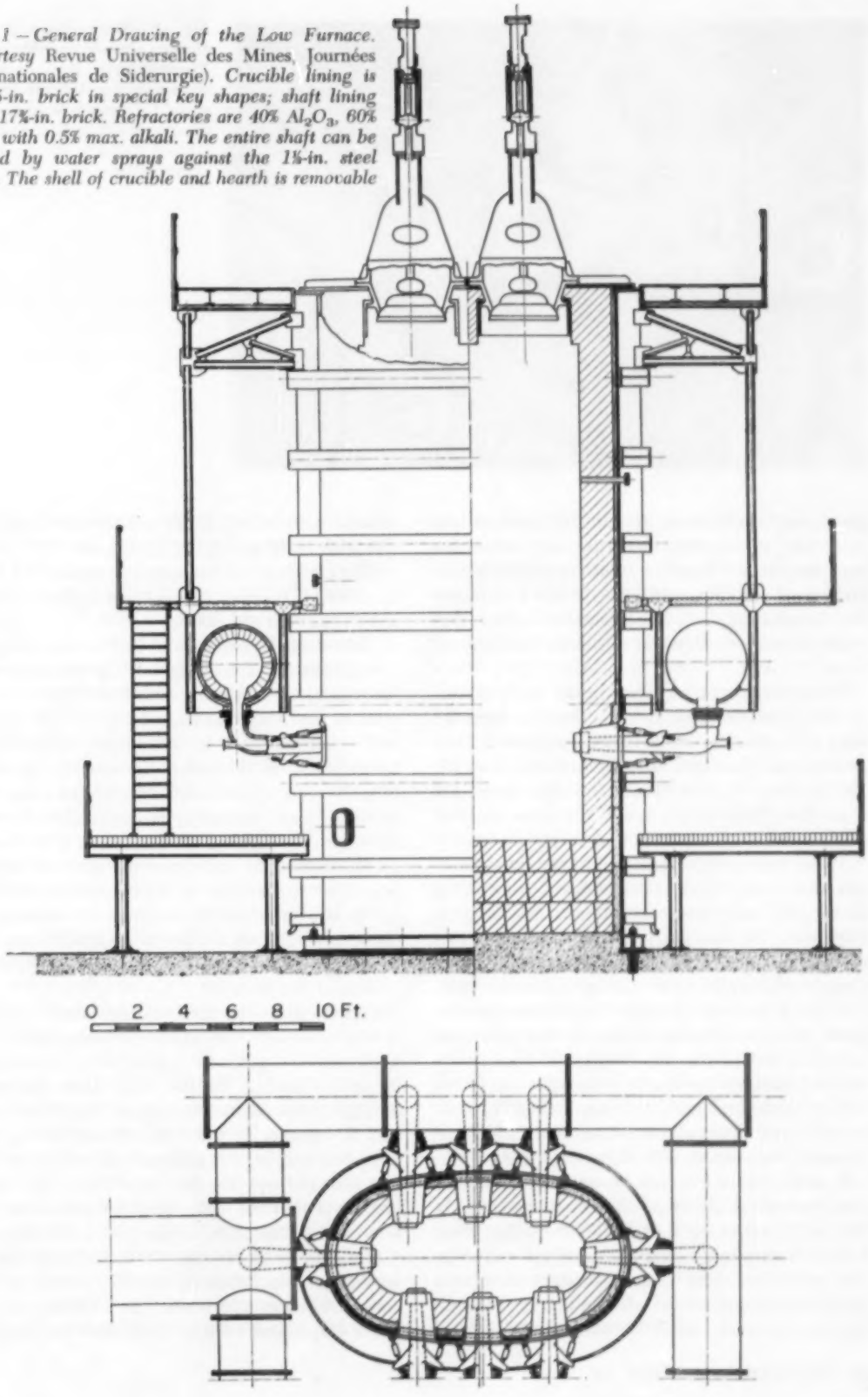
As is described in two articles in *Journées Internationales de Sidérurgie* for August 1953, the stock house has a capacity of 900 metric tons of ore and 450 tons of coke – that is, enough for a five-day campaign. Raw material is transferred to three rectangular silos or hoppers by traveling crane and grab bucket. Each may be discharged at an accurately controlled rate by pan conveyer into a mixer, and the mixer discharges into two skips, each of 28 cu.ft. capacity, which serve the bells at the top of the furnace.

The hearth has a theoretical capacity of 15 metric tons. There are two slag notches and one iron notch. Tapping is at 4-hr. intervals; slag is granulated and iron is pigged.

Early Operations

The first responsibility of the Committee in charge of the low-shaft furnace of Ougrée was therefore to develop and operate an entirely new

Fig. 1 – General Drawing of the Low Furnace. (Courtesy Revue Universelle des Mines, Journées Internationales de Siderurgie). *Crucible lining is of 15-in. brick in special key shapes; shaft lining is of 17¾-in. brick. Refractories are 40% Al_2O_3, 60% SiO_2 with 0.5% max. alkali. The entire shaft can be cooled by water sprays against the 1½-in. steel shell. The shell of crucible and hearth is removable*



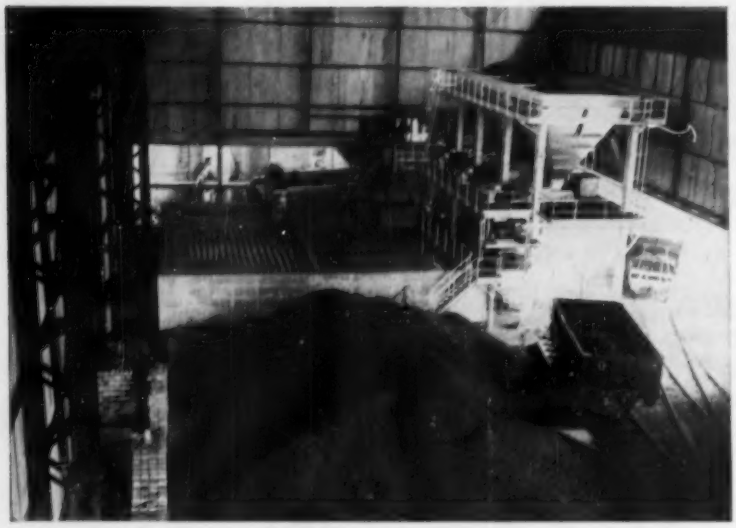


Fig. 2 – View From Stock House Craneway, Showing Three Charge Bins or Silos at Upper Right With Measuring Conveyers Below, and the Pig Beds at Left Center

plant, and at the same time utilize unusual raw materials. It was difficult to proceed otherwise – to begin, for example, with experimentation on normal ore, flux and coke. In the latter case the interrelations of the apparatus to the materials it must treat would not have been known from the start.

Numerous minor incidents, quite independent of the general design, marked the first tests. In spite of these difficulties, we made many valuable observations during three runs between May 13, 1953 and July 6, 1954. These campaigns produced more than 7000 metric tons (7700 short tons) of cast iron.

These tests were begun with calcareous and siliceous ores from Luxembourg, containing about 26% iron, screened to granules ranging from 10 to 30 mm. (0.40 to 1.20 in.), but it also contained from 20 to 30% of sizes below 10 mm. Ougrée coke of 10 to 30 mm. size was the fuel.

These tests were continued with Lorraine ore from Piennes containing 34% of iron and considerably finer: 30 to 50% through 10 mm. (– ⅜ in.) and balance between 10 and 20 mm. (– ¾ + ⅜ in.), smelted with coke from Ougrée, Zeebrugge and Cockerill, together with additions of coke breeze up to 20% of the total fuel.

Finally, the last campaign used the Lorraine ore Ida with 31.5% iron, – 20 + 10 mm. (– ¾ + ⅜ in.), containing 8 to 14% of fines (less than 5 mm. or through 4-mesh sieve). Fuel varied in this campaign. The basis was semicoke from Bruay containing 12% of volatile matter; then to this semicoke we added 25% of coal with 24% of volatile matter, and finally added 25% of anthracite with 12.5% of volatile matter.

The air blast, on the average, was about 700° C. (1300° F.), either normal atmosphere or enriched to about 28% oxygen.

The following conclusions can be summarized:

Segregation of materials while charging the furnace is to be strictly avoided. This furnace, with its low height and narrow cross section, has low "inertia" and is extremely sensitive to irregularities in the composition of the burden. Moreover, irregular distribution of the materials, as in all shaft furnaces, is responsible for unsymmetrical working of the furnace, involving partial fusion too high up in the stack at certain points, or appearance of unprepared material in the hearth at others. It is therefore essential to insure perfectly regular feeding with uniform distribution of the materials over the entire cross section of the furnace.

Particle Size – In the tests with very fine ore, it was observed that relatively large coke – 20 to 40 mm. or ¾ to 1½ in. – gave better permeability to the burden. On the other hand, the zone of high temperatures was raised simultaneously and the quality of the iron suffered, being low in carbon and high in silicon, and flushing of the cast iron and the slag became difficult. The conclusion is that the coke should have about the same size distribution as the ore in the furnace.

Addition of finer coke to the charge had a very favorable influence on the quality of the cast iron (especially raising its carbon content) but a large part of this small fuel is found in

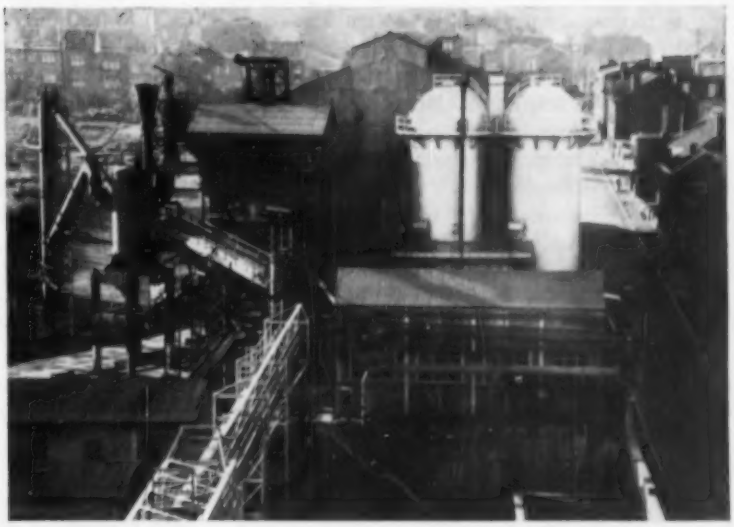


Fig. 3 – General View of Experimental Plant. Stoves at right center, blast furnace with gas handling and cleaning equipment at left; stock house at rear. Blowing engines are in smaller building in right foreground

the flue dust, whose carbon content might reach 30 or even 40%. Excellent results have been obtained when using Bruay semicoke, smaller than ¾ in., carrying 10 to 20% of volatile matter.

Fuel – With this fuel and Ida ore, operating with a burden yield of 28.6% (dust deducted), a carbon consumption of 1145 kg. per metric ton of iron has been attained. Dust losses in this were about 300 kg. per ton of iron, half of it consisting of the finest particles of the ore (less than 0.5 mm.), and half of it fine fragments of semicoke. This operation, with a blast of 28% oxygen, gives a gas of 538 Btu. per cu. ft., and an iron low in silicon (0.2%), high in carbon (3.66%) and acceptable sulphur (0.115%).

These results, obtained with equipment not fully perfected, are encouraging and probably can be bettered. They indicate that a normal Thomas iron can be obtained starting with fine ore and a fuel based on noncoking coal. Daily production during this test was around 40 tons.

Top Gas – Trials using coal with 24% volatile matter and anthracite with 13% volatile matter were also carried out with 28% O_2 blast. About 25% of these fuels were added to the semicoke. The following observation is of interest:

The top gas produced in the low furnace with these fuels contained no tar and hardly any hydrocarbons, but had a high hydrogen content. It might thus be thought that the use of enriched air brings about the existence of a small combustion zone with a high temperature gradient and a relatively cold stack, so that the hydrocarbons are decomposed before being picked up by the gas. This encourages further trials using raw coals – at least anthracite.

Shaft Temperatures – We have referred to the high thermal concentration caused by enriched air. This was anticipated. In fact, the low throat temperature is precisely the reason why a low-shaft furnace can operate.

Indeed, it can be said that during smooth runs giving useful observations with a 28% O_2 blast at around 700° C. (1300° F.), the top temperature rarely surpassed 150° C. (300° F.) and the height above the tuyeres of the zone of red heat did not exceed 1.25 m. (4 ft.). In the zone immediately above, the temperature fell rapidly to 200 and even 100° C. This explains why, in spite of high CO and even hydrogen in the top gas, the furnace gasses cannot play the part of useful deoxidizers; the materials are too cold. The increase in coke rate for direct reduction which results is partly compensated for by increased calorific power of the top gas. This naturally would have to be evaluated according to local conditions.

Oxygen content of the blast was increased to about 32% during one test without trouble but did not lead to any special conclusions.

The rate of enrichment has been generally maintained at around 28%. Certainly during the next campaigns it will be advisable to try blasts with various enrichments so as to determine the optimum oxygen content for a given mixture of ores, and at the same time obtain a sufficiently cool top gas, desirable production rate, regular descent of the charge, and a minimum of dust.

It is possible that the use of high top-pressure will permit an appreciable reduction in oxygen requirements, making operations less costly, but certain defects in the top construction have prevented such an attempt to date.

In any event, we have been able to determine, as was anticipated, that the low-shaft furnace accepts with difficulty a high volume of ordinary air blast. Experiments in this direction have caused extensive hanging, "chimneying", high top temperatures, and a great amount of dust.

General Observations on Operations

We have observed that the thermal efficiency of the apparatus is very good. This is probably due to the concentration of the high-temperature zone. Thermal losses, when producing no more than 40 tons of iron daily, are actually less than 10% of the total calories involved – that is to say, are not as much as in a normal blast furnace in heavy production.

Another consequence of the use of oxygen and of the resulting high temperatures is that we can use very basic slags ($CaO:SiO_2 = 1.7$ to 1.8), tap iron at high temperature (1400 to 1500° C. or 2550 to 2730° F.), and therefore, in spite of high sulphur input, we are able to make iron of low silicon content whose sulphur does not exceed 0.125%.

On the other hand, it seems that the existence of a narrow zone of very high temperature, with cold materials above (as in certain electric furnaces or producers) causes the formation of partially fused layers in the form of an arch which opposes the regular descent of the burden. We observed these crusts several times at the limit of the combustion zone by probing with steel bars.

It is probable that systematic movement by small-scale hanging and slipping in a more or less regular manner (which has always been observed on the low-shaft furnace blown with enriched air) is due to the existence of these crusts. It is possible that in future better distribution of the materials will partially remedy this inconvenience – as may also the studies on optimum oxygen requirements.

Limits on Fines – This phenomenon of hanging – which has so far made the operation of the low-shaft furnace a delicate problem – also depends on other factors, primarily on the very fine fractions in certain of the ores that are put into the furnace.

Thus, it has been clearly proven that the furnace can consume satisfactorily "small" ore – for example, granules between 5 and 20 mm. (0.20 to 0.80 in.). It was also clearly proven that it acted like a vacuum cleaner for very fine fractions and particularly for particles smaller than 0.5 mm. (0.01 in.); the effect was most marked for those below 0.002 in.

Whenever we observed a marked increase in dust production there was simultaneously a marked propensity toward hanging. The only way we found to correct this (and the cure is not completely satisfactory) was to stop charging and run with a furnace only partly full. Unfortunately, this remedy accentuates difficulties resulting from faulty distribution of the material in the furnace, because of the increased free fall to the stock line.

Even though we were able on occasion to use up to 65% of small coke (through 10 mm. or ⅜ in. screen size) in the charge, it is possible and perhaps probable that fines less than 0.3 mm. (50-mesh A.S.T.M. standard sieve) must be screened from the charge. Commercial use of moist, fine ore would therefore in all likelihood involve drying and screening, the final products being put on one side for agglomerating (not necessarily sintering).

However that may be, we think that the heavy dust losses – as much as from a blast furnace – could be considerably reduced if the lines of the furnace top were refined and perfected.

Many modifications of the charge and charging methods were attempted during the tests; we have charged separate beds of coke and ore arranged in different ways, and we have also charged well-mixed materials. We noticed that a charge in separate layers had better permeability than when well-mixed, but since our mixing devices and the present distribution of material at the throat left something to be desired, we were unable to draw any worth-while conclusions from this fact.

It remains to note that the 5½-in. tuyeres originally installed in the low furnace proved unfavorable, probably because of excessive wall action. Liners of 3.1 in. inside diameter and later tuyeres of 60 mm. (2.36 in.) were used. The latter appear to be satisfactory. It is probable that the tuyere size should be varied with the enrichment chosen for the blast. In general, it may be observed that, in spite of its small diameter, the low-shaft furnace requires a minimum velocity of blast into the hearth.

Such is in outline the story of the low-shaft furnace during the year of work which has just come to an end.

The Copper Industry in Australia

*By A. L. SIMMONS**

Fig. 1 – Locations of Main Centers of the Australian Copper Industry

The dilemma of finding more ore reserves for a metal which is suddenly needed in plenty now confronts the Australian copper industry. The production from new workings, started in recent years to meet the demands of an expanding industrialization, posed a problem for a time because of the industry's inadequate refining capacity; today the problem concerns the rapidly dwindling 12-year supply of domestic ores. Fabricating capacity, comprised of a number of young and technologically modern companies, will soon be adequate to meet foreseeable needs.

IN PREPARING this paper for the Third International Review of Metallurgy in *Metal Progress*, the Australian Institute of Metals decided to report on the copper industry because, although it is small in terms of tonnage output, it is up to date technologically and has many peculiar problems in supply and demand. However, this article will be limited to a general outline of the main features of the industry and some relevant statistics.

Historical – The copper industry in this country started in the 1840's with the discovery and mining of deposits in South Australia. Others were found and worked in Western Australia and New South Wales at about the same time, but

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all of these early workings have long since been abandoned. The most important deposits now being worked are Mt. Morgan, Mt. Lyell and Mt. Isa (see Fig. 1). Two of these started as mines for other metals – Mt. Morgan for gold and Mt. Isa for lead and zinc. In 1906 a smelting plant was built at Mt. Morgan to win the copper from the ores that were increasing appreciably in content. Copper was not mined at Mt. Isa until 1942 when war needs justified suspension of lead-zinc operations in favor of copper.

Although copper smelters were established early, it was not until 1908, when a smelter and electrolytic refinery was erected at Port Kembla, that refining was carried out regularly. The refinery was later extended to treat blister copper from Mt. Morgan as well as from other sources. By 1928 the Mt. Lyell company installed its own electrolytic refinery, and those two tankhouses are still the only ones in operation. The first fabricator commenced operations in 1916 and this industry has since grown extensively.

Main Features of the Industry

By world standards Australia's output of copper is insignificant, amounting to only 1.5% of the annual world production of 2,750,000 long tons. The word "insignificant" must, however, be considered in its relationship to the producing country – so far as Australia is concerned our copper industry is of great importance and vital to our well-being in peace and war.

First, let us take a brief look at Australia itself. In area, it is almost as large as the United States, but has a population of only 9 million, or about 6% of that of the U.S.A. Most of these people are concentrated along the eastern and southeastern seaboard and in the capital cities of the eastern states, especially in the cities of Sydney, Melbourne, Adelaide and Brisbane, which contain 4¼ millions. This extreme urbanization leaves the remainder of the country very sparsely populated.

Australia is a young nation, not much older than 150 years. Until the latter part of the 1800's our industry was almost entirely agricultural and it is only since the first World War, and particularly during and since the last War, that secondary industry has grown to any size. This growth has taken place very largely in the capital cities and has led to the concentration of population already mentioned. One difficulty arising from this trend is that, as the cities become the centers of fabrication and consumption of metals, high transport costs are involved in moving raw materials and partly finished metals from inland to the distant coastal cities.

The degree of development of secondary industry in a country is reflected in its per capita consumption of metals. For instance, consider the following figures for copper consumed in 1952:

U.S.A.	17.5 lb. per capita
Canada	17.8
United Kingdom	15.2
Australia	11.5 [only 6 lb. in 1923]

Let us now consider how this rapidly increasing demand is met. Prior to the 1914-1918 War Australia was a substantial exporter of copper; production reached a peak of 47,000 long tons in 1912. Over the past 30 years the depletion of richer deposits has gradually reduced production. This decline and the increased consumption have forced the importation of copper. Except during adverse economic times and during periods when surpluses accumulated (as during World War II and during 1952-1953 when consumption decreased sharply), exports have been held to the minimum. Exports of copper-bearing materials have for some time been licensed by the Commonwealth Government; very little is exported except certain refractory concentrates, mattes and speisses which are uneconomic or difficult to treat locally. With the recent (1953) emergence of Mt. Isa as a copper producer, the total production of metal is approaching 40,000 long tons per year, as compared with 15,000 for the period 1946-1952, and imports have decreased. Counteracting this is the expected demand of 55,000 to 60,000 long tons per year of new copper for the next few years, and this will steadily increase. Australia's all-time high in copper consumption was 55,000 long tons of new copper in 1942 and about 50,000 long tons in 1951.

The country has imported copper in the raw state (blister, wire bars, ingots and wire rod) and in considerable quantity as semifabricated materials (sheet, strip, rods, sections, tube and wire). The import of semifabricated materials (we call them "semis") has been decreasing as the capacity of the local fabricating industry has increased. Previously, blister has always been preferred to refined copper as an import because spare refining capacity was available. Now that Mt. Isa is producing in quantity as a smelter, but without an associated refinery, electrolytic refining capacity has been overtaxed and even the recent refinery extensions cannot process all

Fig. 2 – Aerial View of Port Kembla, Showing City of Wollongong in Distance, Works of the Electrolytic Refining and Smelting Co. in Center Foreground and of Metal Manufactures Ltd. in Right Foreground

of the blister that is produced in Australia.

Fire-refined copper is a commodity for which there has been no market in Australia; Mt. Isa blister is of high grade and fire-refined copper produced from it falls just under high-conductivity requirements. The only current solution to the lack of electrolytic refining capacity appears to be the fire refining of the surplus blister. The Mt. Isa company has had some success attempting to create a market for products made of fire-refined metal, particularly for copper sheet and copper for alloy manufacture.

A large proportion of our copper goes into public works and public utilities programs, new industry and new construction. Copper wire and strand require about half of the total, the remainder going into other copper and copper alloy semis. Some new copper is used in the foundry industry but the main source is secondary metal, which in recent years is estimated to comprise about 25% of total copper consumption.

Figure 1 shows the location of the major operations of the Australian copper industry. The total employment in all branches of the industry, from mines to fabricators and cablemakers, is about 10,000 persons.

Mining, Smelting and Refining

Mt. Isa Mines Ltd. produce both copper and lead-zinc ores. The copper ore is reverberatory smelted and then converted, and the blister sent to Port Kembla (Fig. 2) for electrolytic and fire refining. The ore mined by Mt. Morgan Ltd. is by open-cut methods and blister is produced by reverberatory matting furnace and converter. The blister is sent to Port Kembla for recovery of the copper, gold and silver.

The Mt. Lyell Mining and Railway Co. Ltd. operates possibly the lowest-grade open-cut copper mine in the world. Blast furnace matting and converting are used to produce a high-grade blister, which is electrolytically refined direct without intermediate refining in an anode furnace. The cathodes are sent to Port Kembla for casting into market shapes.

In addition to the smelters at the mines, a fourth smelter, together with an electrolytic refinery and casting shop, at Port Kembla, is operated by the Electrolytic Refining and Smelting Co. of Australia Pty. Ltd. As well as refining blister copper from Mt. Isa and Mt. Morgan, and casting cathodes from Mt. Lyell, the company smelts concentrates from small producers, treats purchased scrap copper and copper-bearing residues and produces copper in market shapes. (See Fig. 3.)

Australia's total copper-producing capacity is about 300,000 long tons per year of charge for the matting furnace, about 55,000 long tons per year for the bessemer converters, and about 37,000 long tons per year of cathodes. Casting capacity for copper wire bars and ingot bars is about 50,000 long tons per year and for copper billets about 12,000 long tons per year, but the capacity for these items is being increased. The copper production for recent years and major ore reserves are shown in Table I.

Capital investment in copper mining and refining is around £A.20,000,000 ($45,000,000).

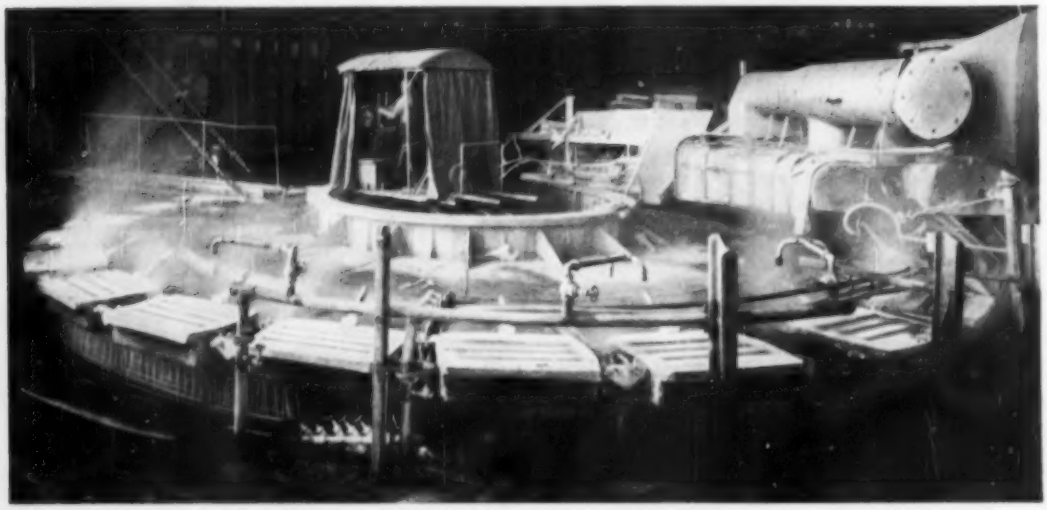
The Fabricating Industry

With minor exceptions, the scope and capacity of the Australian copper and copper alloy fabricating industry are sufficient to meet all our requirements. As indicated above, a limiting factor in output has been the shortage of refined copper. In recent years there has been a marked expansion of fabricating capacity, and this expansion is still proceeding.

The largest of the major fabricators is Metal Manufacturers Ltd., which started in 1918 with the production of copper bars and rod, wire and strand. In 1918 the production of copper and brass tubes was begun and in 1923 paper-insulated telephone cables. Since then the company has transferred cable manufacture to other firms in which it has a financial interest. Its main factory is at Port Kembla, adjacent to the copper refinery, and it has a smaller factory at Melbourne. The company's products include copper and cadmium-copper rolled rod and wire, brass rolled rod, trolley wire (grooved and round), a wide range of copper and copper alloy tubes (see Fig. 4), stranded copper conductor, and copper wires with various kinds of covers. This firm takes the greater part of the output of the Port Kembla refinery and is the largest Australian consumer of imported copper.

The Austral Bronze Co. Pty. Ltd., second in size, is a wholly owned subsidiary of Metal Manufactures Ltd. Originally a foundry, the company started rolling rods at Sydney in 1916. Since then it has expanded and now has plants at Sydney, Melbourne and Hobart, the main plant being at Sydney. The company's principal products are extruded rods, bars and sections, and rolled sheet and strip. In addition to these products of copper and copper alloys it also makes some foundry ingot and some aluminum alloy extrusions.

Fig. 3 – Casting Copper Market Shapes From Wire-Bar Furnace at Electrolytic Refining and Smelting Co., Port Kembla



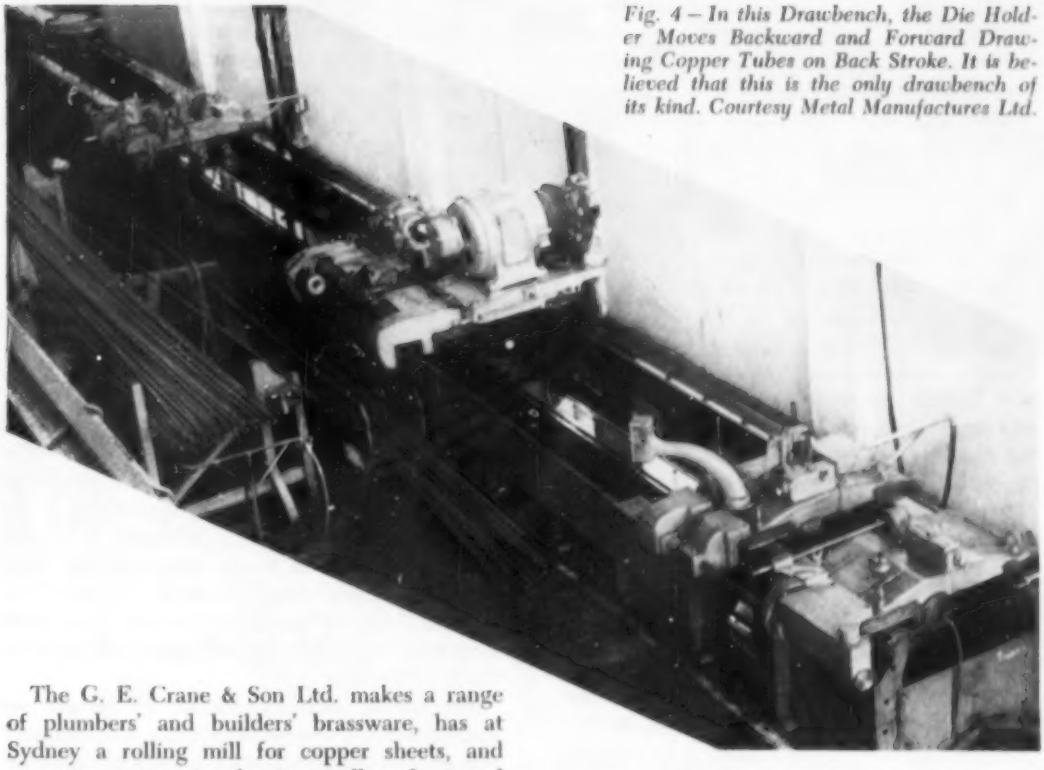


Fig. 4 – In this Drawbench, the Die Holder Moves Backward and Forward Drawing Copper Tubes on Back Stroke. It is believed that this is the only drawbench of its kind. Courtesy Metal Manufactures Ltd.

The G. E. Crane & Son Ltd. makes a range of plumbers' and builders' brassware, has at Sydney a rolling mill for copper sheets, and operates a separate aluminum alloy sheet and strip mill. In addition, there are numerous smaller firms fabricating copper and copper alloys. The most important are Metallex Pty. Ltd. and Extruded Metals Pty. Ltd., which produce extrusions, and Mytton's Ltd. which roll nickel silver mostly for flatware and cutlery production. These three firms are located in Melbourne. In Adelaide there are two small extrusion plants. In time of trade shortages government ammunition factories have produced copper alloy sheet and strip for commercial applications.

Wiredrawing and covering and cablemaking facilities are extensive. In addition to Metal Manufactures Ltd. copper wire is produced by many re-drawers; several obtain the feed from Metal Manufactures. Of the cablemakers the most important are Australian Standard Cables Pty. Ltd. of Port Kembla, which makes paper-insulated lead-sheathed telecommunications cables up to 1500 pairs, enameled and textile-covered lead-sheathed cables, cotton braided cables, and co-axial cables; British Australian Power Cables Pty. Ltd. of Port Kembla, which makes paper-insulated oil-impregnated lead-sheathed or aluminum-sheathed

Table I – Production and Reserves of Copper in Australia

Producer	Production (Long Tons)					Reserves, Copper Content
	1950	1951	1952	1953	1954	
Mt. Isa (blister)	—	—	—	5,477	19,868	152,000
Mt. Morgan (blister)	3,614	4,168	5,651	6,237	5,474	180,000
Mt. Lyell (blister)	5,563	6,721	8,027	9,356	8,606	339,000
Others* (refined)	1,971	2,172	2,921	3,291	2,978	—
Copper in bluestone†	607	599	711	284	1,109	—
Total	11,755	13,660	17,310	24,645	38,035	671,000

*Includes copper produced at Port Kembla from miscellaneous copper and gold ores, copper-containing residues from lead and zinc operations, and miscellaneous copper-bearing materials.

†Includes some copper of secondary origin, so that the totals are inflated to some extent as a result of both this and the impurity contents of the blister.

power cables; Cablemakers Pty. Ltd. of Sydney, manufacturing cables with insulations other than paper; Olympia Cables Ltd. of Melbourne, which produces a wide range of most types of cables and various winding wires. There are also many smaller cablemakers making specialties.

The forging of copper alloys in Australia is mainly in the field of hot brass pressings for such application as plumbers' and builders' hardware, refrigerator components and similar items. Copper alloy foundries range from repetition foundries for small work up to large jobbing foundries established in shipyards, the latter producing copper alloy castings weighing up to 35 tons. There is an extensive secondary metal industry with facilities for segregation, remelting, alloying and ingoting of scrap as feed for foundries and the smaller fabricators. The bulk of extrusions is produced from secondary metal.

The capacity of Australia's copper and copper alloy fabricating industry is given in the following tabulation, in long tons per year:

Fabricated Product	Capacity
Wires and cables	45,000 to 50,000
Tubes	8,000 to 10,000
Sheet and strip	15,000 to 17,000
Extrusions	15,000 to 18,000
Castings	30,000 to 40,000
Total	113,000 to 135,000

To satisfy this capacity fully (except for the foundry industry, which is grossly in excess of requirements) would require close to 70,000 long tons of new copper annually; hence a large proportion of this capacity is idle at present.

An analysis of the industries using copper products in Australia in 1951-1952, the latest date for which such information is available, reveals that the electrical and construction industries each consumed about 25,500 long tons of copper products (mostly as wire for the former and as ingot and the usual commercial shapes for the latter); the transport industry used 2710 long tons, and the other industries 10,000 long tons. In that year the consumption of copper scrap was 14,000 long tons.

Conclusion – Until 1953, when Mt. Isa resumed production, Australia had to import approximately half of its copper requirements. At present there is a deficiency which must be met by importations, and this deficiency is expected to increase with the extra demand arising from the gradual increase in total population and the increase in per capita consumption accompanying increasing industrialization.

The mining outlook is bleak. Known ore reserves represent only 12 to 14 years' requirements, and there is no indication of any new mines of significant size coming into production within the next ten years. (It must be remembered, however, that there is tremendous scope for systematic mineral prospecting in Australia, particularly in the undeveloped interior; it could happen that large deposits may be found – the important discoveries of uranium in Australia in recent years exemplify such a possibility.) At Tennant Creek in central Australia, a copper deposit at depth is being developed by Peko (Tennant Creek) Gold Mines N. L., and it is expected that the output will reach about 4000 long tons yearly, but this will give little relief to the total demand.

Fabricating capacity, except in certain restricted fields where some capacity is in excess of foreseeable needs, will soon meet Australia's requirements for a number of years. Expansion is under way, or has recently been completed, to meet the demands of those parts of the industry in which the capacity was deficient. This applies to some fields of rolling, extrusion, wiredrawing and cablemaking.

The state of Australia's copper industry since the 1920's has been one of feast or famine, depending on world prices. Australian prices for copper and copper products have had to follow world prices; otherwise local producers and fabricators are undersold by the imported article. In recent years the local industry has been assisted to some extent by tariffs and import restrictions. At the time of writing another review of the tariff position is being made.

Acknowledgments – The author has drawn freely from official publications of Australian Commonwealth Government Departments, in particular from those of the Bureau of Census and Statistics, of the Bureau of Mineral Resources, Geology and Geophysics, and of the Division of Industrial Development of the Department of National Development. The following publications of the latter division go into considerably greater detail than has been possible in this paper:

"The Structure and Capacity of Australian Manufacturing Industries", 1952.

"Brief Review of the Australian Non-Ferrous Metals Industry, Part I, Copper and Copper Alloys", April 1953.

"Survey of Manufacturing Capacity in Australia", April 1954.

The following volume contains a number of detailed papers on the primary metallurgy of copper in Australia:

"Extractive Metallurgy in Australia, Non-Ferrous Metallurgy". Fifth Empire Mining and Metallurgical Congress, 1953. Publications, Vol. IV B.

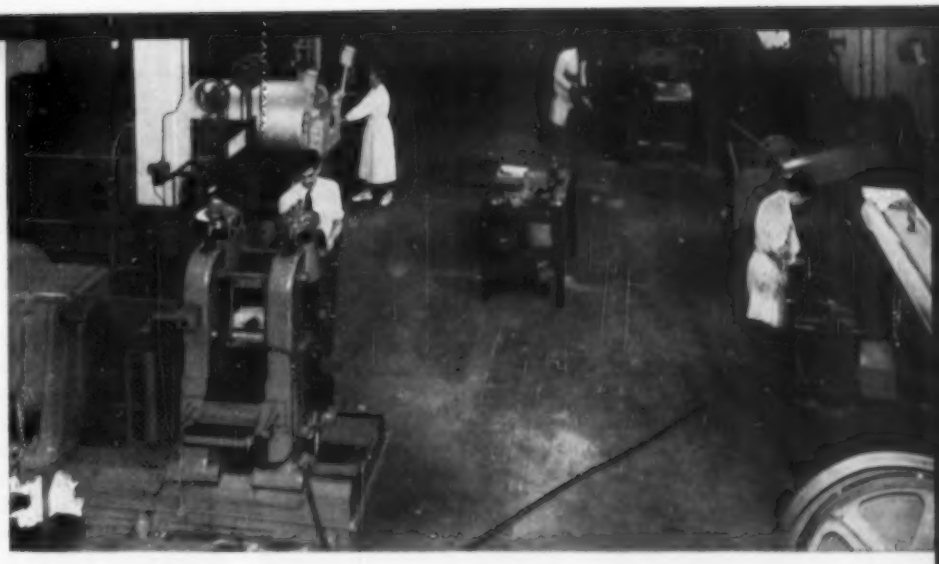


Fig. 1 – The Metalworking Shop. 12 x 12-in. rolling mill in foreground; 500-ton extrusion press at top left; forging hammer at top right

The British Non-Ferrous Metals Research Association

*By B. [illegible]LLMAN and E. C. MANTLE**

Typical of some 40 British research associations supported by industry with some government assistance is the Non-Ferrous Association with more than 600 member firms. In addition to the principal job of conducting fundamental and applied research, it provides a consulting service for solving specific problems and an information service, all free of charge to members.

THE BRITISH Non-Ferrous Metals Research Association is an organization of some 600 member firms, each of which pays an annual fee in proportion to its size and interest in non-ferrous metals. Results of its research are made available equally to all subscribing members, each of whom receives in addition certain other privileges without charge – namely, a confidential consulting service and an information and library service. (Routine testing is excluded.) In effect, the relatively small subscription paid by a member gives it all the benefits of a considerable research program plus a comprehensive technical service.

There are now some 40 British research associations of this general type. Until recently unique to the United Kingdom, such organizations are now being established in various countries in the British Commonwealth and in Europe. A word or two about the history of the movement, therefore, would not be out of place.

Early in the first World War the British Government concluded that better use ought to be made by industry of scientific knowledge. In 1915, therefore, it established a Committee of the Privy Council for Scientific and Industrial Research, and a year later established the Department of Scientific and Industrial Research as a separate entity, having its own financial

*Respectively Chief Information Officer and Chief Liaison Officer, British Non-Ferrous Metals Research Association.

arrangements and responsible to Parliament through the Lord President of the Council. Among its duties was the promotion of the use of science in industry by all possible means, but primarily through a scheme for cooperative industrial research associations. The general method is to encourage any British industry, through its constituent firms, to form a cooperative research association on the understanding that the funds provided by industry will be supplemented by a grant out of funds allotted to the Department of Scientific and Industrial Research. This method of operation continues to the present day.

Although the Department adds to the funds of the research associations, and government representatives serve on their councils, it should be emphasized that the associations are autonomous bodies free to conduct their own affairs without any pressure from the Government. A government department may sometimes sponsor a project with a certain research association, but contracts of this kind are paid for by the particular department quite separately from the grant provided through the Department of Scientific and Industrial Research.

Organization of the Association

The British Non-Ferrous Metals Research Association, inaugurated in January 1920, was one of the earliest of these research associations. By the end of the first year there were 20 company members and the total income was only £6000. By the end of 1953, membership was more than 600 and the total income more than £134,000 (about $375,000), of which the government grant was £36,200 ($101,700).*

Membership is open to any company in the United Kingdom or the British Commonwealth which produces, fabricates or uses non-ferrous metals. Members range from the greatest industrial giants to small foundries, electroplating, or galvanizing firms. Many engineering firms that are users but not manufacturers of non-ferrous metals are also members.

Most of the Association's research work was carried out extramurally (as in universities) until 1930, when a laboratory was opened on the present site. This has been greatly expanded, until the total floor area is now over 45,000 sq.ft. and the staff numbers 150. The only present extramural research is by financial contributions to the fundamental investigations into metalworking undertaken by the British Iron & Steel Research Association.

The Association is governed by a council of representatives of the member companies, elected at its annual meetings. G. L. Bailey has been director of the establishment since 1944, having previously been deputy director and chief liaison officer.

Research Department – The work of the Association is carried out by three departments – research, liaison, and information. The research department is organized into sections, each headed by a team leader. These seven sections are melting and casting (including extraction metallurgy), general metallurgy, mechanical testing, corrosion, metal finishing, physics (including spectrography), and analytical chemistry. At the moment there are 42 major research projects in hand. With most of the projects, one investigator will be primarily engaged in carrying out the work under his section leader, with one or more assistants.

The general research program is laid down by a "Research Board" of leading personalities in the non-ferrous metals industry, who are able to take a broad view of the industry's needs. The Board acts on the advice of five industry committees, whose responsibilities are respectively aluminum, magnesium and their alloys; copper, nickel and their alloys; lead and tin; zinc and galvanizing; chemical and electrochemical finishes. These committees meet annually to consider what new tasks are to be undertaken and what existing researches should be terminated.

Specific researches are carried out under the guidance of small research committees drawn from member firms with specialized knowledge of the subject under consideration. At the conclusion of the work or at suitable points in its progress, reports are released which are confidential to member firms. Because of the diversity of interests, no attempt is made to circulate all reports automatically to all members. However, every member receives the monthly *B.N.F. Review*, a confidential document which reviews all the reports of the previous few weeks, together with short notes on other technical matters of interest. The reviews are short, easily digested articles which indicate the aims of the research work and the practical results achieved without going into details of experimental methods. The full reports are immediately obtainable for further study by any member firm

*It should be remembered that living and other costs are much lower in the United Kingdom than in the U.S.A., so this conversion at the current rate may be somewhat misleading.

on request. The *Review* was started some six or seven years ago to meet the need for some means of disseminating the practical results of the research work to an ever-growing membership.

Much of the research work (about 30 papers annually) is published in the technical press. Publication is not, however, automatic and a time lapse is provided for members to exploit the practical conclusions; in some instances the work may remain on the confidential list. Members' rights are also safeguarded by seeking appropriate patent protection for discoveries. Member firms have the right to exploit the patent at a nominal fee.

While the main function of the Association is to conduct its research department for the benefit of the producers, fabricators and users of non-ferrous metals, the services provided by the liaison and information departments, although subsidiary to the research effort, are of great importance to a large proportion of the member firms.

The Liaison Department has a number of functions. With a membership as large as 600 firms, personal contacts are of course desirable. The department now has eight members of graduate status, and through their visits members are kept aware of the work of the Association and, in turn, problems confronting the members are brought to light.

The department also provides a confidential consulting service to assist members with their day-to-day problems. This very popular service is provided without additional charge and at present the department is receiving some 1200 inquiries each year. These cover a wide range of problems, such as production difficulties, service failures, and advice on suitable materials for new applications. They are received by mail, telephone or personal visit. The specialists in the research department are freely consulted in connection with these problems, and the success of the service can doubtless be attributed largely to the fact that the members of the liaison staff, chosen for their practical information and industrial experience, are backed up by the research staff. There is never any hesitation about visiting a member's plant for consultation where desirable, or about collaborating with members in experimental work.

This service is entirely confidential and problems received from a member are never discussed with a third party without permission. It is also a condition of the service that replies to an inquiry are confidential, and, although the member can discuss the information with other parties, he is expected not to disclose the source without permission of the Association. These conditions prevent the Association's reports from being used for sales propaganda, which would destroy the impartiality of its position.

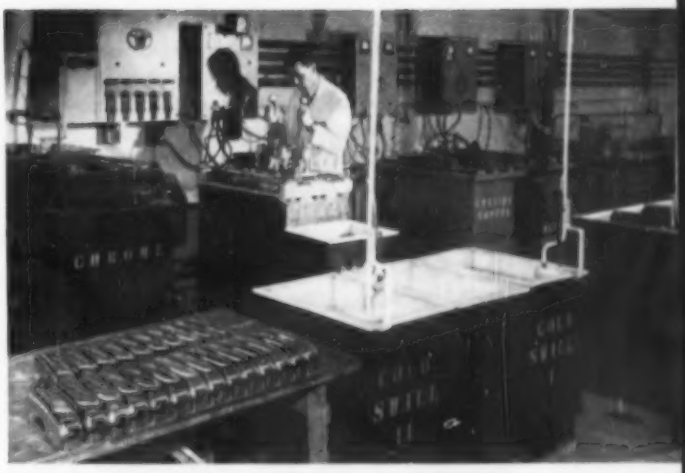


Fig. 2 – Part of the Electroplating Shop Where Two Pilot-Scale Plating Lines Are in Continuous Operation

The liaison staff is responsible for producing the material for the *B.N.F. Review*, and also for organizing practical development work, arising from research in the Association's own laboratories. Small member firms often require considerable assistance to make use of our research results. Demonstrations often have to be given by the liaison department or the member company's personnel trained in the use of new techniques.

Information Department and Library – The function of this department is to provide recorded information to the Association's own staff and to member companies. The Information staff numbers four science graduates and the Library staff four.

The library contains about 5000 volumes, more than 250 periodicals, and a unique collection of 30,000 reprints, preprints, photocopies and other forms of separates. It is well indexed, kept up to date, and old literature is weeded out. (On the rare occasions when a discarded piece is required it is easily obtainable from general scientific libraries.)

The information department surveys the literature, and publishes an abstract bulletin covering about 250 papers a month; current British patent specifications are also listed with titles expanded

to indicate content. The *B.N.F.M.R.A. Bulletin* is not a confidential document, but is generally restricted to British Government departments and the Association's membership.

The Information Department also makes searches of the literature in answer to numerous inquiries. Such searches are restricted to information based on the records; any discussion involving operating techniques is passed over to the liaison department. Translations are provided, as far as time permits (some 30 a year). Russian, German and French are done on the spot, and translations from other languages are occasionally obtained from external sources.

More than 9700 items of literature (books, journals and papers) were loaned to members by mail alone in 1953. A still larger number of loans was made internally to the research staff.

Examples of Research Projects.

Since the Association's inception nearly 150 major researches have been undertaken on many aspects of extraction, fabrication, founding and finishing of metals. A few examples from past and current investigations will serve to illustrate the kind of work done.

Support for the Association at the beginning came largely from the copper industry and an early project culminated in the publication in 1937 of "The Effect of Impurities in Copper" by S. L. Archbutt and W. E. Prytherch. This work was usefully extended during the last War when the United Kingdom was forced to use copper from unusual sources.

In those early days brass strip was being produced mostly by cold rolling in small mills from relatively thin ingots or slabs cast in cast iron molds. The difficulties experienced in making good-quality strip from these ingots led to an extensive research, the results of which were published as "The Casting of Brass Ingots" by R. Genders and G. L. Bailey (the present director). This has become a classic work on the subject, and is still in demand 20 years later. As a result, water-cooled copper molds have now to a large extent superseded the old cast iron molds. A study of the Durville casting technique for aluminum brasses was also included in the investigation.

Perhaps the most notable of all the Association's early work was the development of alloys for marine condenser tubes, in cooperation with the British Admiralty and the leading tube manufacturers. The key to the Association's success was probably the development of the May jet

Fig. 3 — The May Jet Test. Two specimen holders have been removed from the tank to show the jets. Sea water is delivered to the air mixer at top by a tube rising through the hollow pillar in the center of the stoneware vessel. The sea water containing entrained air bubbles issues from the jets at 15 ft. per sec.

test, which simulates the conditions encountered in marine condensers. Test pieces immersed in a trough of natural seawater are subjected to the impingement of streams of fast-flowing seawater containing entangled bubbles of air (Fig. 3). All but the most resistant alloys are attacked, the severity of the attack depending to a large extent on the degree of contamination of the seawater.

Research using the May jet test led directly to the discovery and patenting of aluminum brass (76% Cu, 22% Zn, 2% Al), an alloy which has since been used extensively for tubing condensers, oil coolers, and other heat exchangers. Later work resulted in the development of iron-bearing 70-30 cupronickel for condenser tubing and a range of copper-nickel-iron alloys. This research is still in progress.

The expanding use of light alloys during the 1930's, especially in the aircraft industry, called

for a study of such things as microporosity in magnesium alloy castings, gas unsoundness in aluminum alloys, freezing characteristics and their relation to hot tearing, inverse segregation, and metal-mold reactions. Many of the findings have been so completely absorbed into industrial practice that it is difficult to realize how little was known about fundamentals only a couple of decades ago!

The Association was a pioneer in spectrographic analysis, and "Collected Papers on Metallurgical Analysis by the Spectrograph", edited by D. M. Smith and published by the Association in 1945, is a standard work on the subject. The department possesses some of the most modern equipment, and has developed special source units. An additional function of the spectrographic department is to provide an analytical service to the research and liaison departments, and no less than 2400 samples are handled each year, involving the estimation of about 12,000 elements.

A few of the other subjects investigated in the early days included the properties of soft solders, the atmospheric corrosion of non-ferrous metals, and alloys for permanent mold casting.

Current Researches — A large expansion of research facilities took place after the war, and advantage is being taken of developments in physical metallurgy.

X-ray crystallography has played an important role in several recent programs, such as the recrystallization of aluminum alloys with special reference to the grain growth in extrusion; work on directional properties in high-strength aluminum alloy extrusions; and a study of extrusion conditions for brass to avoid coarse grain on reheating prior to stamping. An electron micrograph taken in connection with a study of the structural changes occurring in copper-nickel-iron alloys during heat treatment was awarded a medal for "Best in Class" at the ⊕ Metallographic Exhibit during the 1950 National Metal Congress.

Foundry work has always been prominent in the Association's activities and the laboratories possess crucible furnaces, high-frequency furnaces, a vacuum furnace, billet, sand and permanent-mold casting facilities and shell-molding equipment. Experimental alloys made in the foundry are rolled or forged in the metalworking shop, which is equipped with a 12 x 12-in. rolling mill, 500-ton press, a forging hammer and a draw bench. Recent investigations are those by Cibula on the mechanism of grain refinement of light alloys and by Ruddle on the mode of solidification of alloys.

In research on titanium alloys for high-temperature service, creep testing equipment of a simple design and capable of giving strain measurements to 2×10^{-5} has been used. The apparatus is robust, occupies little space, and the degree of accuracy is adequate for most non-ferrous alloys. There is also a constant-temperature room for creep tests on lead and its alloys, particularly alloys for cable sheathing. Some factors of fundamental importance to other materials have emerged from this work, such as the influence of grain size on creep resistance and the importance of structural stability.

Not all of the researches are so fundamental in their approach. In some projects, laboratory evaluation of promising materials is supplemented by trials in members' plants. An example is an investigation of refractory linings for melting copper and alloys of higher melting point in low-frequency furnaces of the Ajax-Wyatt type. Another is a detailed survey of the materials used for liners, mandrels and dies for extrusion presses. Each of these investigations began by a round of visits to a series of plants to survey practice and accumulate data for reporting to all members. Similarly, a study of the hot-dip galvanizing process has resulted in recommendations for minimizing dross.

Although the Association has supported work on electroplating for many years, it is only since the War that it has possessed its own metal-finishing laboratory. At present, the main emphasis is on an investigation of bright nickel plating in solutions with organic additions, and two pilot-scale plating lines are in continuous operation. A research on the mechanism of electropolishing has been completed and an improved method of plating on aluminum has been developed. Other work in hand includes bright chromium plating, the mechanism of smoothing during electroplating, and the development of a nondestructive thickness test.

Summing up, after 30 years' existence the Research Association is firmly established as an integral part of the non-ferrous metals industry in Great Britain and forms the focal point for the industry's cooperative technical activities. The results of much of its work have been gradually assimilated into industrial practice, and it can be justly claimed that the improvement in technology in the non-ferrous industry over the past quarter-century owes much to this cooperative research effort. ⊕

Contemporary Metal Processing Techniques in Russia

*By N. H. POLAKOWSKI**

The only knowledge we have of Russian technology is that which Russia wants us to have. In spite of this severe censorship and regulation of the technical reports and periodicals, enough information leaks through the Iron Curtain to give a few clues of the progress being made in a number of its divisions in metalworking. More interesting perhaps than these rather obvious conclusions are the inferences instilled by the studious omission of news from countless branches of metallurgical endeavor.

ANY ATTEMPT to write an up-to-date and well-documented review under a sweeping title "Metallurgical Engineering in Russia, 1954", is bound to end in failure. The reason for this is quite simple: Export of the two principal metallurgical journals *Stal* (Steel) and *Tsvetnye Metally* (Nonferrous Metals) is totally prohibited. Curiously enough, the ban applies not only to the western world but also to the satellite countries; so, access to first-hand information on the major metallurgical processes and operations is made impossible. Textbooks covering these fields can be obtained (occasionally) but, as could be reasonably expected, at least 95% of their contents is common knowledge and such aspects as might be of specific interest because of technical novelty are not adequately covered.

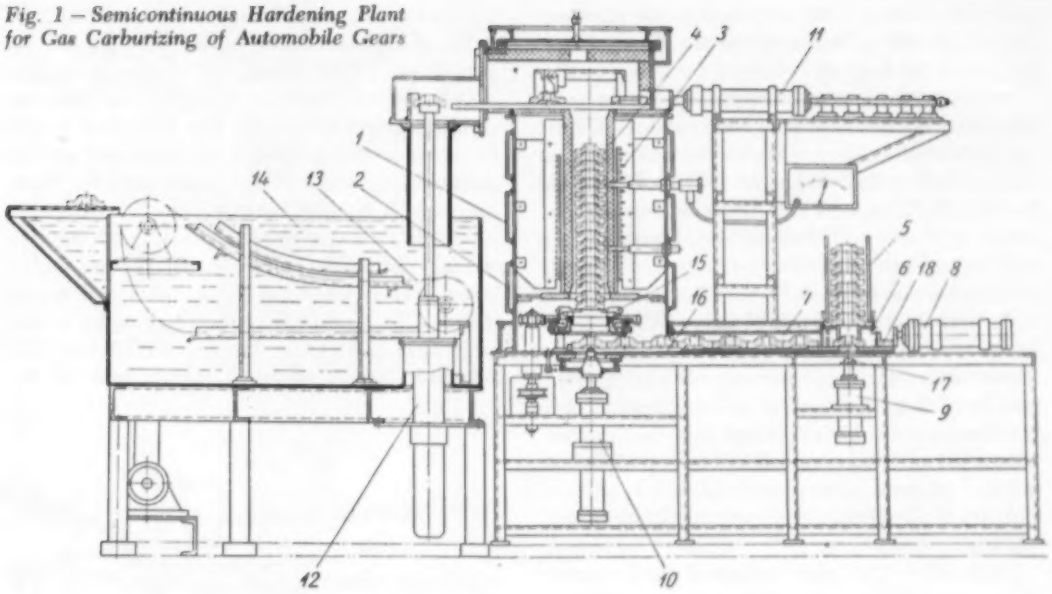
*Consulting engineer, La Salle Steel Co., Hammond, Ind., and lecturer, Department of Metallurgical Engineering, Illinois Institute of Technology.

The situation is somewhat brighter in the realm of secondary metallurgical processes, product engineering, and physical metallurgy. About a dozen technical magazines dealing with machine design and mechanical technology, welding, casting, machining, and several other branches of engineering arrive in the U.S.A. fairly regularly. Most of these have articles devoted to heat treatment, forming processes, joining, surface coatings, properties, and applications of metals in commerce and industry.

It is mainly from these sources that the material for this article has been extracted. In making the final selection the author attempted to include primarily items described as novel or outstanding in the original publications.

Gaseous Carburizing of Automobile Gears With Induction Heat (1954) — The objective of the process was to shorten drastically the duration of the carburizing period while securing a

Fig. 1 – Semicontinuous Hardening Plant for Gas Carburizing of Automobile Gears



case thickness identical with that obtained in a regular box or muffle treatment. This was achieved by using temperatures between 1920 and 1975° F. It was found that austenite grain growth had no detrimental effect upon the mechanical properties of the product, provided that 2010° F. was not exceeded. Case thicknesses from 0.032 to 0.048 in. could be produced in 39 min. instead of the 7 to 8 hr. required for the same purpose in a muffle furnace.

The application of induction heat enabled a complete elimination of equipment such as heating elements and carburizing boxes, requiring expensive and highly strategic heat resisting alloys.

The process was performed in a semicontinuous installation designed and operated by the ZIS automobile works in Moscow. The gears were loaded through the open top into an upright cylindrical magazine closed at the bottom by a hydraulic jack. Every 3 min. the ram descended slightly thereby exposing the side of the lowest blank to a horizontally mounted ram which pushed the gear sidewise through a trough into a position underneath a vertical induction coil energized with 2000-kc. current. At this point a third hydraulic device moved the gear upwards into the actual heating zone.

The gas-filled refractory jacket inside the inductor unit contained a stack of 20 gear blanks at all times; those near the top, being outside the action of the magnetic field, could cool gradually to the correct hardening temperature, whereupon another hydraulic unit would push the uppermost gear off the stack and toward the quenching tank. The path of the material resembles an angular S lying on its face.

The carburizing gas was circulated continually through the furnace, entering at the bottom of the heating chamber and exiting through an outlet in the upper part. Composition of the mixture was 1.5 to 2.5% CO_2, 0.3% O_2, 8 to 11% CO, 22 to 30% H_2, 25 to 32% $CH_4 + C_2H_6$, 31 to 35% N_2.

The installation (Fig. 1) was suitable for treating alloy steels which do not require a double heat treatment, but it could be modified so as to include a grain-refining stage.

Continuous Manufacture of Spiral-Welded Pipes (1953) – A schematic view of the plant is seen in Fig. 2 which is essentially self-explanatory. Coils of steel strip or bands prewelded from single sheets on a flash welder (6) can be employed as primary material. The angle of the helix can be varied by altering the angle between the forming unit (16) and the feeding line (1-15). The detail sketch in the right bottom corner shows the feeding rolls (22), forming device (23), and the electrode and flux feed (24).

This particular installation was designed for pipes of 26 in. maximum diameter. According to another source which refers to similar machines, the pipe diameter may be varied from 4 to 36 in., the wall thicknesses being 0.064 and 0.5 in., respectively. Welding is accomplished by the submerged-arc method at speeds between 2.5

and 7 ft. per min., the lower figure corresponding to the thickest wall. Attempts are being made to increase the welding speed for the heaviest pipes to 8 to 10 ft. per min.

It may not be generally known that Harvey K. Flagler of Boston took out patents about 1875 on "an improved welding machine for making pipes with helical seam". The Spiral Weld Tube Co., Orange, N.Y., realized this invention successfully about 1886 after initial difficulties. Piping of this type was also produced in Germany by Ehrhardt in diameters up to 25 in.

Powder Metallurgy (1946-54) — Although, as in many other fields, the Russians claim priority for inventing the technique of fabricating from powdered metals, their industrial efforts in this field began only about 20 years ago. By then the Moscow Hard Alloy Combine was established for the purpose of supplying sintered carbide tools for the rapidly developing mechanical and fabricating industries.

Until about 1941, this and other plants manufactured tungsten carbides exclusively, and although the advantages of the complex tungsten-titanium carbides in machining applications were well known, the Russians met with no success in trying to discover the technology of making this product. During the last War, therefore, the Soviet Government bought the patent rights and processing details from the Swedish firm which produced the Seco-II Ti-W carbides, considered as one of the best in existence. This, coupled with the plant equipment and scientific manpower "imported" later from Germany, and with the efforts of experts like Umanskyi and Balshin, enabled the Russian sintered carbide industry to achieve a modern level. At present, the range of carbides made in the U.S.S.R. is comparable with what is available in other industrialized countries. It comprises at least five tungsten carbide compositions with 3 to 12% cobalt binder (a nickel binder is used in one of these) and six titanium-tungsten carbide grades with the titanium carbide content varying from 5 to 60%.

A little information of general character concerning the official policy in the powder metallurgy field is provided by an abridged report from the Technical Convention on Powder Metallurgy held in Moscow, January 1953. About 200 delegates, representing 80 bodies such as the U.S.S.R. Academy of Sciences, several industrial research organizations, ministries, universities, and industrial concerns, attended this conference organized by the Metal Economy Committee of the All-Union Council of Technical and Scientific Associations.

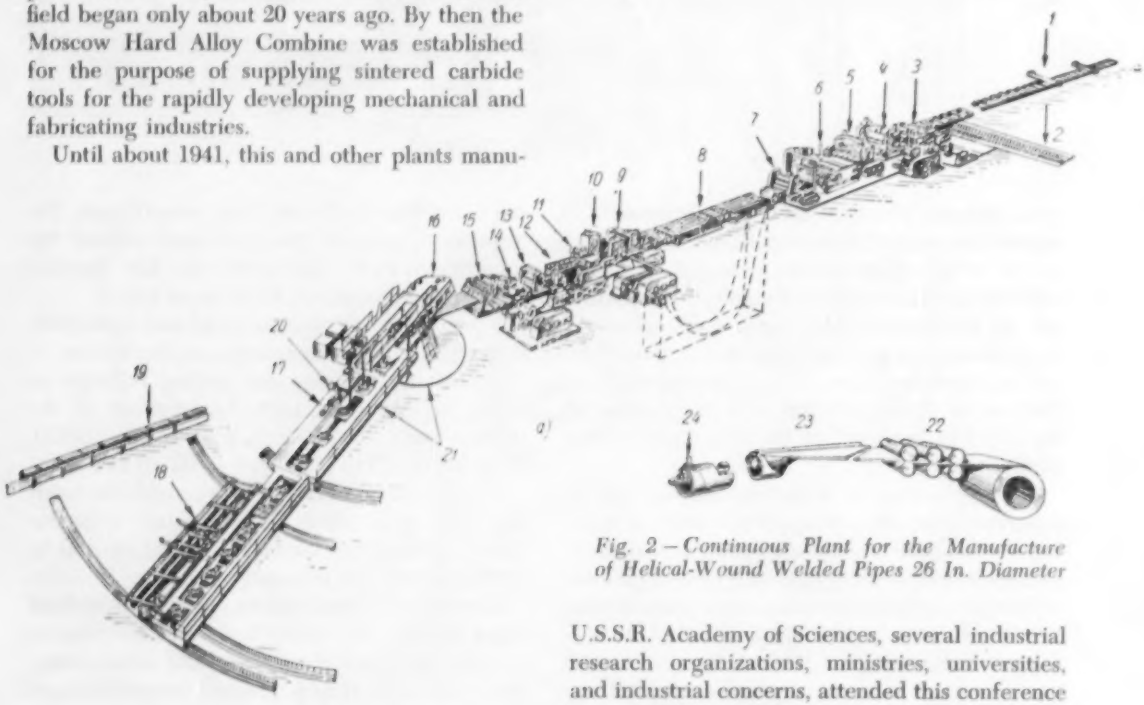


Fig. 2 — Continuous Plant for the Manufacture of Helical-Wound Welded Pipes 26 In. Diameter

Nearly half a dozen papers dealt with production of iron powders by various techniques. Among a number of other claims made it was stated that Russia pioneered the manufacture of powders by atomizing in gaseous atmospheres and by the centrifugal method. Suitable units may have an output up to 5 tons per hour, thereby providing a low-cost powder. An equal number of papers was devoted to iron powder products, mainly to porous iron-graphite bearings for automobiles, belt conveyers, agricultural machin-

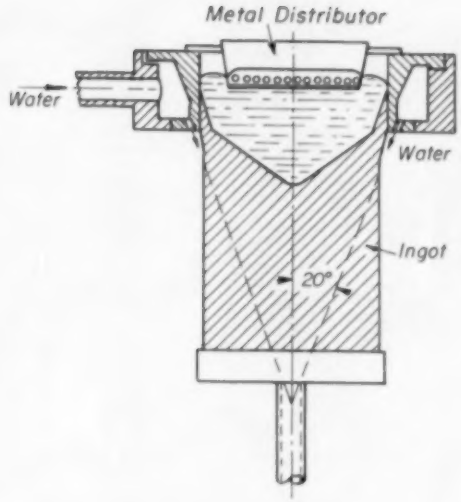


Fig. 3 – Continuous Casting of Aluminum Alloy

ery, and others. Particularly outstanding performance in service was attributed to the parts being impregnated under vacuum with lubricants representing a colloidal suspension of metal particles.

Considerable interest was evoked by the description of a method in which pressing and sintering were performed in one operation with the use of electric current conveyed through the punch. It was stated that good quality products were obtained consistently with low ram pressures and, of course, without a need for special atmospheres.

The main emphasis in the papers and in the ensuing discussion and resolutions was on the replacement, wherever possible, of nonferrous metals by iron powder products. This tune is not new to those familiar with the German efforts in this direction during World War II. There is little doubt that a substantial part of the Russian developments represents either duplication or natural continuation of the German work.

Metalizing and Mechanical Surface Treatments (1953-54) – These subjects hold a prominent place in the list of articles published in all of the Russian technical periodicals. The various and numerous methods employed to harden surfaces – by high-frequency induction or by gas flame, carburizing and nitriding, cyaniding, diffusian and electrolytic chromizing, surfacing with austenitic steels, stellites and carbides with the aid of spraying or electro-spark method, boron impregnation, and others – are reported in profusion and are too numerous to be reviewed in detail here. (There is nothing principally new in these anyhow.) However, it may be worth while to record just a few of the headlines attached to various topics presented during two symposiums held in Moscow in April and November 1953 (the first on the subject of antifriction coatings produced by metal spraying, and the other under the heading "Exchange of Information on Methods of Increasing the Life of Machinery"). So here are some of them: "Bearing Surfaces on Shafts Last Two to Three Times Longer When Prepared by Metalizing With Atomized Steel Than When the Necks Are Hardened by Thermal Treatment"; "Bearings Obtained by Spraying an Al-Pb Pseudo-Alloy on Almost Any Conceivable Shell Show Excellent Properties in Service"; "Coating the Rolls in Hot Tube-Mills With Austenitic Alloy Steel Increases Roll Life Tenfold"; "The Benefits of Shot-Peening on Life of Flat Springs Are Amplified by Peening Under Static Tension"; "Large Savings Are Obtained by Preventive Porous Chromizing of Parts Which Show Incipient Wear".

A large portion of the papers and communications was devoted to repair and reconditioning methods and to case histories rather than to whatever new techniques they may have that are unknown here. Some of the claims made were plainly exaggerated and would be classified elsewhere as overly enthusiastic sales talk.

Automation in Metalworking (1953) – The use of automation is extensive and numerous automatic metal-processing lines are in operation comparable with those of this country. However, such descriptions as were made public refer almost exclusively to the manufacture of motorcar and tractor engine components (ball bearings included).

The greatest volume of publicity was allotted to the automatic factory for pistons completed in Moscow in 1951. From the metallurgist's viewpoint, the most interesting portion of the installation would perhaps be the casting equipment which has been integrated with subsequent operations. Ingots of an aluminum-copper-silicon alloy are fed into a three-chamber furnace, melted down, the metal is poured into successive split dies mounted on a revolving 6-position capstan, the solidified pistons are then extracted, precipitation heat treated, and automatically conveyed to the machining and inspection lines. Some details of other Soviet automatic lines for machining operations were reported recently in the technical press and need not be described again here.

The general impression gained from these

sources is that, notwithstanding the usual loud advertising noise which accompanies even some of the minor "victories" in the automation field, Russian technology can claim a number of achievements in this field. People engaged in the machine tool industry may find materials of interest in the book "Avtomaty" (Automatic Machine Tools), by G. A. Sha'umyan, published in 1952 by Mashgiz, Moscow.

Continuous Casting (1952) – For the reasons given at the beginning the author was unable to conjure a detailed account of the modern developments in this important field. However, the following passage appearing in Gorshkov's "Casting of Ingots From Nonferrous Metals and Alloys" (published by Metallurgizdat, Moscow, 1952) gives some information that may be worth quoting:

"At the present state of knowledge, the method of casting ingots with direct chilling by water, as is used in our country for (continuous) casting of aluminum alloys, is the most advanced in existence. It was developed by Stalin Prize-Winners Livanov, Belov, Moskalenko, and others . . . It can be stated with confidence that this method will be employed in the near future for all kinds of technical alloys and that for mass production purposes it will soon replace all other processes."

These three prize winners are not mentioned in the references at the end of Gorshkov's book; Fig. 3, taken from the same source, seems to represent the gist of the matter. It is left to the reader to assess the degree of originality of the construction which, among other unspecified achievements, should prove, as Gorshkov states, "how far behind has Soviet science left foreign countries." But leaving aside questions of priorities, the net teaching of this brief note is that continuous casting is being carried out in Soviet plants, but just how extensively it is impossible to estimate.*

Automatic Arc Welding of Aluminum Alloys (1954) – Work has been going on for a number of years in the Moscow Automotive and Tractor Institute to devise a cheap substitute for the argon (or helium) arc process. The following abstract of an article should be regarded as a progress report rather than a final solution to this problem.

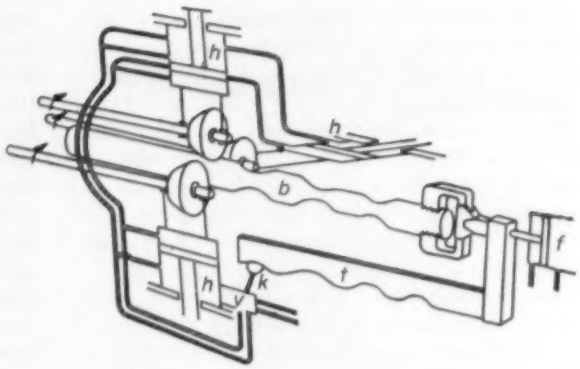


Fig. 4 – Radial Rolling Mill With Copying Device

After trials with different fluxes it was found that the majority of them do not produce a satisfactory stability of the arc and a seam of acceptable uniformity. In welding under a layer of flux (submerged-arc), the weld metal invariably had a high degree of porosity and the removal of slag after welding was difficult. It was decided to use a very thin layer of flux, barely sufficient to perform the essential metallurgical functions on the weld. Welding *under* flux was thus substituted by welding *over* the flux layer.

This change gave very encouraging results, the danger of porosity being virtually eliminated and the welded seam having a sound and uniform appearance.

The comparative experiments were performed on 0.16-in. duralumin sheet using direct current with reversed polarity (25 v., 170 to 180 amp.), a welding rate of 65 ft. per min., and a 0.060-in. diameter duralumin wire as consumable electrode. Satisfactory results were claimed for sheets 0.040 in. thick. The strength of the weldments was about 31,000 psi. after annealing, and between 45,000 and 51,000 psi. after solution and precipitation treatment. Unfortunately, the article contained no details regarding the composition of the flux, a point which would be of considerable interest.

Mechanical Working (1948-53) – In this field, the work of Tselikow (also a Stalin prize-winner) on rotary die forging and radial rolling processes deserves special attention. One of his more interesting constructions is reproduced in Fig. 4.

This machine is identical in principle with a three-roll tube expanding mill but was modified to serve an entirely different purpose. As can be seen on the diagrammatic sketch, all three rolls

*An installation for continuous casting of iron slabs appears in a recent issue of *Liteynoe Proizvodstvo*. There is nothing new in it, the machine consisting of a mold cooled internally by water and followed by two pairs of withdrawing rolls.

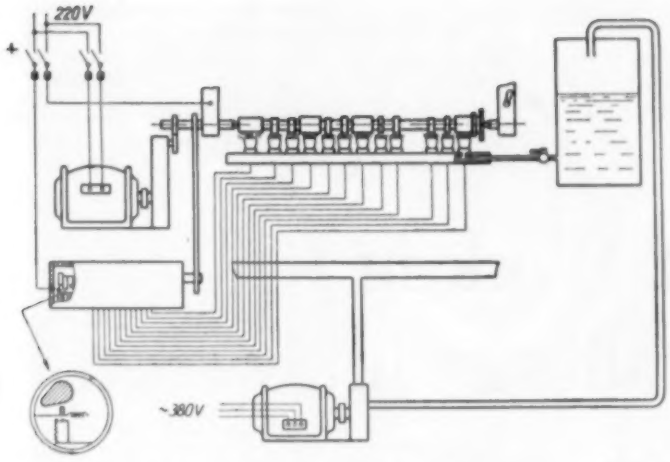


Fig. 5 – Equipment for Electrolytic Hardening of Camshafts, Showing Tank for Electrolyte at Right, Series of Nozzles and Their Electrical Connections, and Recirculating Pumps

can be moved in unison in the radial direction with the aid of hydraulic cylinders *h*. The instantaneous position of the rolls and hence the diameter of the hot bar *b* is governed by the follow-up lever *k* which actuates the hydraulic control valve *v*. This lever is in turn operated by an interchangeable templet *t*.

Bar *b* rotates about its axis and is at the same time fed forward at a uniform rate by means of the feeding device *f*. Since the templet is displaced simultaneously, its profile is reproduced exactly on the bar being processed.

This method offers a variety of possibilities in the mass production of axles, stepped shafts, and other axially symmetrical bodies from steel and other metals.

Among other developments it may be mentioned that Russian-built Sendzimir-type mills have been in existence since about 1950. This may explain how very thin Permalloy and silicon steel strip for intricate electronic controls and radar gear is made over there. This author has never found publications reporting on original Russian contributions to the cold extrusion of steel or hot extrusion of steel tubing.

Electrolytic Hardening – Electrolytic hardening is based on the observation that the cathode in an electrolytic cell, filled with a suitable aqueous solution, is heated at a rate dependent on the current density at its surface. By suitably controlling factors such as voltage across the cell, heating time, bath concentration, and chemistry, steel may be hardened to any desired depth and any temperature right up to the melting point.

The practical applications of this method of heat treatment seem to be largely a one-man project, a Russian engineer Yasnogorodskyi, who worked on it with great persistence since about 1932 (his first paper on the subject was published in 1935). One of his hardening machines (Fig. 5) shows cam surfaces on a tractor camshaft being hardened in pairs, the electrolyte coming out under pressure from suitable nozzles and impinging on the cams.

In certain circumstances this process may be employed in lieu of induction heating over which it has the advantage of being much cheaper. Instead of the expensive high-frequency generators usually required for induction heat treatment, the electrolytic method utilizes ordinary direct-current power sources such as generators or rectifiers of any type.

Although Yasnogorodskyi too received the usual prize for his deeds, the use of this equipment in Russia is apparently limited to those plants where Yasnogorodskyi was employed– that is, to the Kharkov Tractor Works, and to the Altai Tractor Works in Barnaul, Southern Siberia, where Y. works at present. (It may be added that the Altai Works, ATZ, came into existence during the last War, by using the equipment evacuated from the Kharkov plant.)

Although Yasnogorodskyi keeps a modest silence about the source of his inspiration, it can be proved by reference to the *Electrical Review* (London), Vol. 104, 1929, p. 185 and 229, that Paul Hoho and his companion Lagrange investigated this procedure in considerable detail as far back as 1890, and in the intervening years devised a variety of ways by which electrolytic heating could be utilized in industry. It seems appropriate to emphasize this point if only to counter the statement made in a review of Yasnogorodskyi's book that this technique was entirely unknown on this side of the Iron Curtain.

This article was compiled from articles published in *Avtogennoye Delo, Vestnik Machinostroyenya, Liteynoye Proizvodstvo, Avtomobilnaya I Traktornaya Promyshlennost'*, and *Elektrichestvo*, as well as from books purchased via the outlets of Russian literature in London, Paris and New York. As the sources of information become more plentiful, details of other developments may become available.

Fig. 1 – This New Home of Metallografiska Institutet, the Swedish Institute for Metal Research, Was Opened During the 200-year Jubilee of Jernkontoret, (Swedish Ironmasters Assoc.) in September 1947

Some Recent Work in Physical Metallurgy in Sweden

*By ERIK RUDBERG**

Incompleted reactions in solid alloys – metastability – are under intense study, including bainitic hardening of alloy steels, martensitic hardening of 18-8 stainless, and earliest stages of precipitation hardening in nonferrous alloys.

RESEARCH in physical metallurgy is being pursued at several places in Sweden. Many problems related to steel are tackled by cooperative committees of Jernkontoret, the 200-yr.-old Association of Swedish Ironmasters. The larger laboratories of that industry also carry on investigations of their own. Active in nonferrous work, especially, are the laboratories of Svenska Metallverken at Vasteras and Finspang. The departments of metallurgy and of physics at the Royal Institute of Technology in Stockholm do considerable basic research in the field of metals generally. This last remark also applies to Metallografiska Institutet (the Swedish Institute for Metal Research) in Stockholm, which represents a joint effort in which steel, nonferrous and mechanical industries have entered as partners with the Swedish government.

With no attempt at completeness, the following account endeavors to give a glimpse of some of the basic projects which have received close attention in recent years.

Isothermal Transformation – It is appropriate that the name of Axel Hultgren, honorary member of the ⊕, should head the list, though any brief review cannot do justice to this prominent scientist, recently retired from active work at the Royal Institute of Technology. Hultgren's extensive studies on the isothermal transformation of austenite have revealed characteristic differences in the distribution between the transformation products (cementite and ferrite) of a third alloying element such as copper, silicon and nickel – or tungsten, molybdenum, manganese and chromium.

Given sufficient time, the first-named group of elements will avoid cementite and favor ferrite, whereas the latter group will show the reverse preference and concentrate in the carbide phase. Equilibrium distribution sometimes could be established directly during transformations at high temperature where pearlite forms at a moderate rate. Low-temperature transformations, however, were often found to disregard strict equilibrium requirements as to composition; more time is required for adjustment by diffusion. In extreme instances, transformation precipitates the new phases with no change in alloy content.

Hultgren calls these "para-phases" – para-cementite, para-ferrite – in contrast to the true equilibrium or "ortho-phases". It is possible to recognize such partial equilibria – para-equilibria – with the alloy content "frozen in", and to indicate the boundaries of the corresponding re-

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gions in the phase diagrams. It would seem that some of the distinguishing and technically important differences between pearlite and bainite, formed by different heat treatment of the same steel, are linked to this phenomenon of para-equilibrium.

Interesting as these results are by themselves, Hultgren's ideas have aroused much illuminating discussion and stimulated new work in several directions. A few of these may be indicated.

It is a characteristic of true equilibrium (ortho-equilibrium) between two phases that for every component the activity has the same value in both phases. Since activity is controlled by composition, this actually determines the two-phase tie lines and boundaries of single-phase regions in the phase diagram. In fact, it is useful in such diagrams to imagine for each component a family of iso-activity lines, each line joining all compositions for which the activity has a given value and thus representing, in a sense, the corresponding potential level for that component.

Hillert, of the Swedish Institute for Metal Research, has used this concept in a discussion of several problems. He has formulated a number of rules which these iso-activity lines must obey, especially at the boundaries between single-phase and two-phase regions. It may be said that such a diagram or representation can hold no fundamentally new information that is not inherent in the thermodynamics on which it rests. While this is true, it is surprising how useful this pictorial representation is in giving at a glance the important data, and in suggesting the trend of reactions in nonequilibrium or para-equilibrium situations.

Carbides in Alloy Steel – Hillert has shown this rather convincingly by several examples. Some errors in earlier published phase diagrams were soon detected by this method. They violated thermodynamic principles. A typical application concerns carburization of alloy steels at 900° C. (1650° F.). In pack carburizing, some steels may acquire a surface zone containing cementite, formed at that temperature. The condition for this to occur is that the carbon activity, which the carburizing environment forces the steel to breathe, exceeds the activity of cementite in equilibrium with austenite of the particular alloy content. Iso-activity lines show clearly that alloying elements like chromium, which prefer cementite to austenite, depress its carbon activity and hence favor cementite formation; the reverse is true for nickel, which avoids the carbide.

The nature and shape of carbide particles in steel are also attracting considerable attention. Kuo, who collaborated with Hultgren in the work on alloy element distribution, later extended this work to the various carbide phases in molybdenum steel, chromium steel and tungsten steel. Much new information in these ternary equilibrium diagrams was discovered. Much of Kuo's X-ray work was done in Hagg's laboratory at

Upsala. New or modified methods for isolating carbides – largely with the object of determining the shape of the fine precipitates – are being pushed by Heiskanen at Sandviken and by S. and H. Modin at our Institute for Metal Research. Electron microscopy is a valuable tool in this investigation. Comparisons at high magnification of direct electron micros of the isolated particles and replica photographs of the structure *in situ* are particularly revealing. In this work, the Modins have been able to trace, step by step, the isothermal formation of carbide precipitates in carbon steels down to quite low temperatures in the bainite transformation range. See Fig. 2 and 3.

Precision Calorimeter – In the ceaseless endeavor to explore more deeply the mechanism of reactions in solid metals, the need of new, refined and searching tools is often felt. It is therefore natural to find that the advanced methods of micro-calorimetry developed by Borelius and his students at the Royal Institute of Technology are rapidly gaining widespread appreciation. In fact, experimental equipment of this kind, modeled after Borelius's apparatus, is now being put to work in several of the world's leading research laboratories. Some results obtained with this method have recently been described in American journals.

In principle, the method follows the progress of isothermal reactions in solid metals by measuring the rate at which heat is developed in the sample under study, causing it to maintain a temperature very slightly above that of its accurately thermostated surroundings. Measurement of the minute temperature differences, and calibration by comparison with a known rate of heat supply, are of course all done electrically. The reaction rates span a range from runs that demand weeks of observation, to processes so fast that electronic recording devices are required. The rate of heat evolved by the reaction usually is measured in micro-watts.

Early Stages of Precipitation Hardening – Borelius has applied this technique to reactions of three types. One is the "recovery" of cold worked metals such as aluminum, copper and zinc. At a fixed recovery temperature the rate of heat evolution is found to be inversely proportional to the time since the beginning of the recovery process – to a very good approximation. The rate increases rapidly as the temperature is increased. Experiments of this kind may be expected to play an important role in the development of dislocation theories for plastic deformation of metals.

The other two types of reactions to which Borelius has applied his micro-calorimetric method are order-disorder processes (such as have been studied successfully by other means – notably in the Au-Cu system) and precipitation from supersaturated solid solution. In the last-mentioned category, especially, much recent study has been devoted to precipitation in aluminum supersaturated with copper or with silver. Other systems have also been looked into, such as lead-tin alloys, and the very dilute but supersaturated solutions of carbon in alpha iron.

Interest in these precipitation reactions, which are also studied by electrical resistance, X-rays and internal friction (damping) in Borelius's laboratory, stems not only from their technical importance, but from the scientific problem of nucleation prior to visible precipitation. Borelius's theory is based on certain extensions of thermodynamic ideas; recent experiments have enabled him to verify the theory quantitatively in several instances with remarkable success.

No brief report can do justice to this, but it may be remarked that Borelius's theoretical treatment regards a compositional change in the earliest stage, with its attendant change of energy and entropy, as the dominating feature in nucleation. It thus neglects, as a first approximation, factors such as surface energy which, according to other current views, should be important in determining the critical size of the embryo capable of forming a nucleus.

Hardening of 18-8 Stainless – An interesting contribution to our knowledge of diffusionless transformation in solids is the work published by Angel of Sandviken on martensite formation in 18-8 austenitic stainless steels as governed by deformation, temperature and chemical composition. Tensile test bars, slightly tapered toward the middle so as to present a measurable range of deformation and stress within each bar, were pulled at a series of constant temperatures from liquid air up to +50° C. The bars had been finely engraved with a coordinate network for accurate measurement of deformation. Magnetic measurements, X-ray diffraction and electron microscopy ascertained the structural changes involved. In the low-temperature range almost 90% of the austenite could be made to transform by deformation. Looking at the tensile experiments in a different way, it may be stated that at low temperature the deformation is almost entirely ascribable to the transformation of cubic austenite into tetragonal martensite. Major evidence on this conclusion is derived from electron

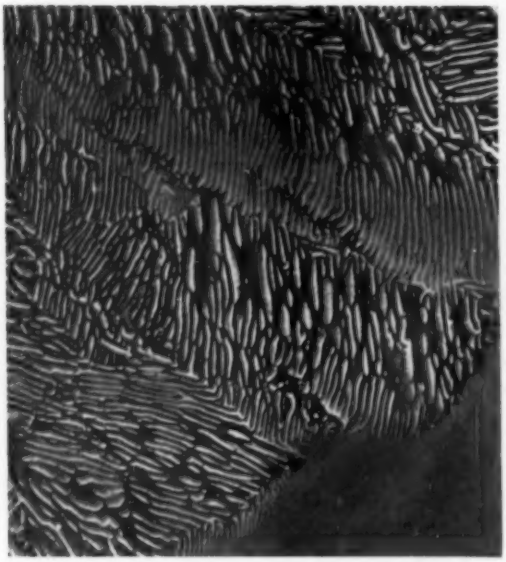

Fig. 2 – Formvar Replica of Pearlite Formed From Austenite at 600° C. in a 0.86% Carbon Steel. Nital etch, 10,000 ×

Fig. 3 – Carbide Particles in 0.86% C Steel After Isothermal Transformation at 600° C. 40,000 ×. (Micros courtesy S. and H. Modin)

micrographs. The somewhat more voluminous tetragonal martensite lattice, together with a preferred orientation of the martensite in the direction of the stress, provides for plastic deformation of the bar as a whole, *without slip!*

As the temperature is raised in successive experiments with different bars, a "transition region" of temperature is eventually reached, where the other mode of deformation – slip in the austenite – takes over. For the purpose of description this region may be characterized by a suitably defined "transition temperature". The lower this transition temperature, the more stable the austenite with respect to the martensite transformation. In this sense, all the alloying additions studied – carbon, nitrogen, silicon and the metals manganese, chromium, nickel and molybdenum – are stabilizers, carbon and nitrogen having a particularly strong effect.

Deformation of a test bar at low temperature, when part of the deformation is accomplished by martensite reaction and part by slip, yields a harder product than though the bar were "cold worked" at room temperature to a similar degree, involving slip only. This excess hardness is closely proportional to the amount of martensite formed during low-temperature deformation.

In this connection mention should be made of a quite different martensitic reaction, the one which takes place under certain conditions in alpha brass. A great deal of new information on this diffusionless transformation and on some other related reactions in brass has recently been obtained by Strom and Bassi, working at Svenska Metallverken in Vasteras.

Fracture and Corrosion – The reader may already have found this list of researches tiring, and yet, to the reporter, it is vexingly incomplete! The careful studies of mechanical properties of mild steel by Josefsson and by Matton-Sjoberg, both at Domnarvet; the many-faceted work on a number of corrosion problems by industrial laboratories, jointly and individually; the new experimental and theoretical attack on fatigue and brittle fracture largely associated with Schaub at Fagersta; not to mention the various research projects connected with the properties of welds and of welded structures – these are only some which rightly belong in the picture of Swedish research today.

International Exchange – However rudimentary, it is hoped that this brief survey will have conveyed some idea of activities in metal science in Sweden. It should at least be clear that the problems with which we grapple are those which are in the minds of those studying metal in other countries. Insofar as this is true, any progress achieved should be of universal interest. By the same token, free interchange of ideas and results is indeed an increasingly important catalyst for the promotion of research, and for the efficient use of the knowledge so secured.

Residual Stresses– How Dangerous Are They?

*By WALTER SOETE**

In sound structures residual stresses help propagate brittle fracture at low temperature, affect the yield point, and increase corrosion rates. In structures or machine parts containing minor physical discontinuities, residual stresses may induce brittle fracture at low temperature.

IN TECHNICAL literature the words "residual stress" are very often used in such a way that the reader might think a residual stress is somehow different from the "stress" he became acquainted with at the very beginning of his study of mechanics. This uneasy feeling is intensified when we realize that steel structures are designed with an "allowable" stress of 17,000 psi., yet we find experimentally that certain portions of such a structure may be carrying "residual stresses" up to 35,000 psi. when the structure as a whole is unloaded and would be considered absolutely safe. So let us at the outset inquire into this matter of semantics.

An Inclusive Definition of Stress

"Stress", in the standard works on mechanics or elasticity, is derived from the concept of "force", generally in the following way:

We suppose a body in equilibrium under the action of external forces – let it be a simple beam supported at its ends and loaded in the middle. We then imagine it to be cut across at some place we want to study, and we put in the drawing a system of arrows representing the forces which must act against or along this imaginary plane in order that the portion under study remain where it is and not fly or spin off in some direction. If any of these forces (tension, compression, shear) is divided by the area upon which it is acting, then the result is a figure we call the "stress".

It is obvious that this classical concept of stress must be connected with the notion of external force. In elastically or plastically deformable bodies, stresses may arise for other reasons than external forces – for example, by local heating, by nonuniform heat treatment, by mechanical shaping or even in a rigid structure by definite deformation of a distant member.

A strict logician might argue that a tug, twist or push some place inside a piece of metal caused by something besides an external force is not a "stress" at all – but since no one could possibly defend this conclusion it is necessary to introduce a more general definition of the word "stress".

With deformable bodies – and certainly our metals of construction are deformable in the circumstances under which they can be used – the concept of stress must always be associated with a concept of deformation. To illustrate: Take a piece of mild steel and heat it above the critical range – say to 2000° F. The "elastic properties" we associate with mild steel (in sizable pieces and at room temperature, by the way, at which nearly all our testing is done) are lost. The atoms in the individual crystals of austenite are vibrating with thermal energy, but X-rays are diffracted as though each iron atom is occupying a place in space which is geometrically indicated by a position in the cubic crystalline lattice. Each atom occupies a neutral or average position, as it were. Each atom exerts some attraction on its neighbors, yet this is balanced by a set of equivalent repulsions. Should conditions change so that an atom is displaced from this neutral position, it could come within the sphere of action of an adjoining atom, and to remain there would require some force of attraction or repulsion to be exerted on it. The resultant of a large number of such forces displacing the atoms which populate a finite plane may be defined as "stress".

Such a definition of stress says nothing about the reason for the appearance or nonappearance of the atoms within the spheres of action of adjoining atoms, since stress may occur for many

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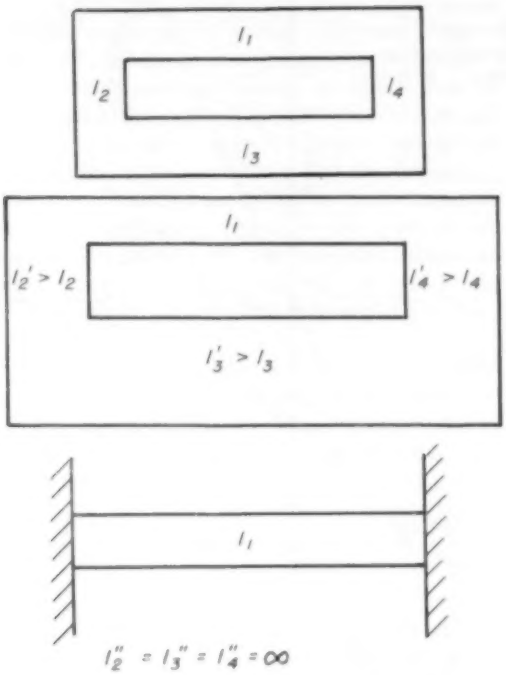


Fig. 1 – Square Frames, Wherein Top Member Has the Same Rigidity I_1. A tension stress induced in it will cause equal stresses in the other members of the frame sketched at top; much less stress in the other members of the middle sketch; and vanishingly small stress in the infinitely rigid supports that are assumed in the bottom sketch

reasons – some within the metal, others external to it. Likewise, such a definition is a poor basis upon which to compose formulas, such as Hooke's law that strains are proportional to the stresses which cause them. (Indeed, this loses its meaning at atomic dimensions.) It does avoid, however, the old notion that stress is an internal force per unit area *caused by external loads*, and that "residual" stress is an internal force per unit area which is caused by something other than external loads.

Reaction, Indirect, Residual Stress

Another related difficulty with nomenclature should also be cleared up, and that is the phrase "reaction or indirect stresses".

Suppose we consider a framed structure or a body with multiple connections: We can introduce stresses into it without causing outside forces to act upon it. As there is no external loading, these new stresses would answer a definition of "residual stresses" but, since they appear only in bodies with multiple connections, they are often called "reaction or indirect stresses". In their effects, however, they are absolutely identical to the stresses produced by external loads.

To illustrate this, consider the closed frame shown in the top sketch of Fig. 1, so designed and constructed that all four branches have equal rigidity–that is, that

$$I_1 = I_2 = I_3 = I_4$$

Now if any one of these branches were cut across, shortened a little, and then reunited as by welding, stresses have been set up, not only in the welded branch, but also in the others.

However, the values of the stresses depend on the dimensions of the members, as is evident from the middle sketch, where a frame is constructed so three of the members are much more rigid than the fourth, namely,

$$I_2 > I_1; \qquad I_3 > I_1; \qquad I_4 > I_1$$

Again shorten I_1 as before, and it is evident that the stresses in the three more rigid members will be less than those in the slender one.

Finally, when we pass to the limit and three of the four members are exceptionally rigid, we have the case of a simple built-in beam or beam with "rigid" end connections as shown in the bottom sketch of Fig. 1. Stresses which may now arise in an unloaded beam of this sort would no longer be called "residual" stresses, but "reaction" stresses, since in all probability they would be due to misalignment or other maladjustments in the connections. Similar is a continuous beam over three supports, one being slightly out of line. Stresses induced during erection by forcing the connections may behave exactly in the same way and effect exactly the same atomic movements as would result from external loads.

A related point and we are finished with this necessary definition of terms.

Closed Versus Open Construction

Structural engineers use the terms "multiple-connected or closed construction" and "simple-connected or open construction". We who are interested in problems of elasticity and strength of materials may ask whether a plate which has a hole cut in it should be considered as an open or a closed construction. Suppose the hole to be quite small; does the notion of simple connection then disappear? In other words, should we consider a weld containing a slight flaw as an open construction or a closed construction?

Without attempting to resolve this dilemma, we can conclude this portion of the discussion by saying that the concept of "residual stress" was apparently introduced because the classic term

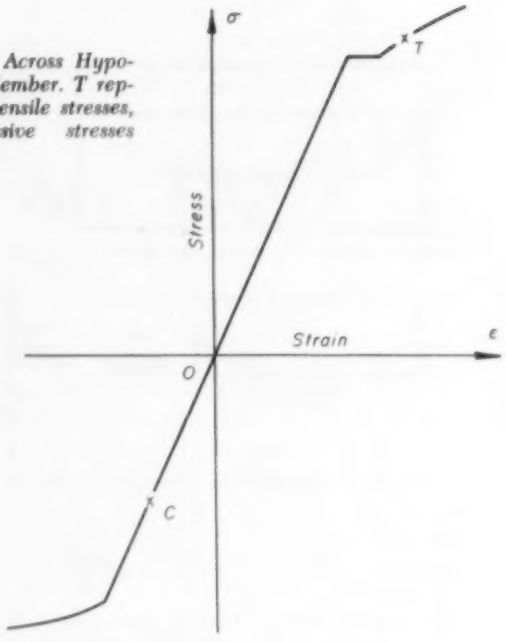


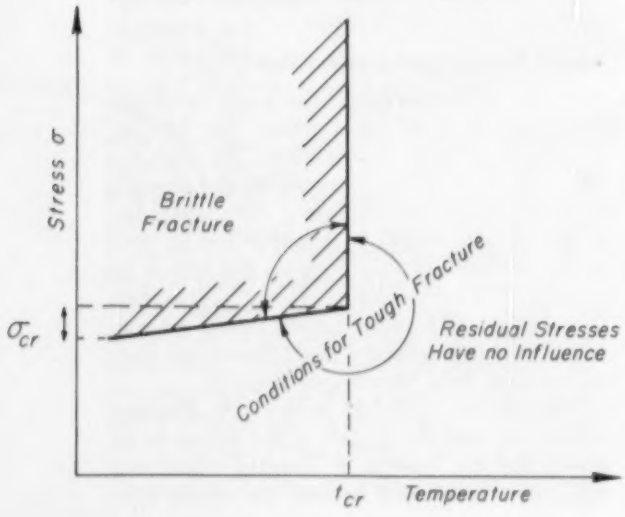
Fig. 3 – Stress-Strain Curve Across Hypothetical Cross Section of a Member. T represents resultant of residual tensile stresses, C of assumed compressive stresses

"stress" was too limited, despite the fact that the metallic atoms cannot recognize any difference. They are both caused by forces occurring in the material; both have definite influence on the behavior of the metal. Such differentiation as has existed in the past literature has usually depended upon the nature of the structure itself. The main reason for using the term – as will be done in the following article – is to distinguish by "residual stresses" those forces existing within a piece of metal, be it a simple part, a built-up member, or a fabricated structure, which are induced in it by its manufacturing, fabrication or erection methods, or by some conditions of its service other than the application of those external loads which the engineer has considered in designing its proportions.

The Principle of Superposition

All works on the theory of elasticity consider the principle of superposition – that is, the proper combination of stresses arising from external forces differing in location, direction or intensity. It is remarkable how scrupulously this matter is evaded in discussion of residual stress. Very seldom does one read of the possibility that stresses from external forces may affect the intensity, nature or effect of residual stress. Some authors candidly admit their incompetence to handle this topic.

Fig. 2 – Relationship Between Stress, Temperature and Ability of Carbon Steel to Arrest Propagation of Brittle Fracture, According to Robertson



Possibly for this reason, all the work which has been expended on the measurement of residual stress has been of less use than anticipated. Nevertheless, it is far from being an academic question to the structural engineer. He is vitally interested in the effect which internal stress may have on those over-all manifestations of the properties of metals he has relied upon for so long – yield point, ultimate strength, fracture appearance, elastic recovery, fatigue strength, resistance to corrosion.

Despite a truly enormous amount of work, our present knowledge about these matters is in a confused state. It is fair to state that European structural engineers are apprehensive and believe that residual stresses can be much more dangerous than they actually are – except under certain fairly well-defined conditions.

Residual Stress and Brittle Fracture

Internal stresses left by the welding operation have received the blame for several spectacular failures in recent years to bridges, storage tanks and ships. As pointed out by Professor Shank in his article in *Metal Progress* last September, such failures occurred long before the days of welded construction; furthermore, much work in various countries has found no evidence that residual stresses are the prime cause of brittle failure.

More recently, experiments by T. S. Robertson in Great Britain and the Standard Oil Develop-

ment Co. in the United States show that residual stresses might induce brittle fracture *if* certain other conditions are also present.* In these tests, the metal is assessed through its ability to stop the spread of a crack. Temperature and nominal transverse stress are factors which, when plotted one against the other, show that by decreasing the stress there is a sudden drop in the temperature at which the progress of the crack is arrested. For most steels, this transition occurs at low stress, and the temperature at which the crack is stopped varies little as the stress increases above the transition.

Conditions for a representative carbon steel, tested at temperatures between — 60 and + 120° F. are shown in Fig. 2. It may be concluded from such work that for temperatures higher than the transition or critical temperature (t_{cr}) the

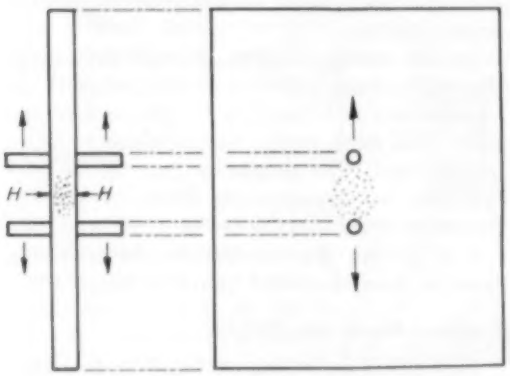


Fig. 4 — Experimental Device to Induce Tensile Stresses in a Heated Spot in a Steel Plate, and Then to Superimpose External Tensile Load by Pulling on the Studs as Shown

value of the nominal stress has no influence on the fracture appearance. No matter how high the stress, the fracture will be "tough" or "fibrous". On the other hand, if the temperature is below t_{cr}, the nature of the fracture depends on the value of the nominal stress; if the stress is high the fracture will be brittle; *if low the fracture will be tough.*

It may be concluded, then, that residual stresses by themselves may propagate brittle fracture under these embrittling conditions:

1. A crack, existing or caused by external factors.

2. Temperature below the "critical transition".

3. Residual stress higher than the critical fracture stress.

Superposition of Static Loads

Yield point and ultimate strength might be influenced by residual stresses during static loading. Although there is no essential difference in the nature of stresses from external loads and "residual stresses", the manner in which the external loads are applied will influence the behavior of the structure according to whether the prior or residual stresses exist only at isolated regions or whether they are widespread.

Assume no external load but residual stresses over a given section — a resultant tension stress T (Fig. 3) at a certain point in equilibrium with a compression stress C. (Since the relative position of these resultants depends on the dimensions and cross section of the hypothetical section, it is quite possible that the compression stress be very small and the tensile very high — or vice versa.) Now if an external load is applied to the structure — say, a total load which induces a uniform tensile stress along the member under study, points T and C move up along the stress-strain curve. Conversely for a total compression load. Or the external load may be such that it only affects a part of this member and either point T or point C could move up or down, according to circumstances; the load will then be *local.*

Local Loading — Strictly speaking, local loading in the above sense is impossible. One cannot load a zone in which there are residual tensile stresses without affecting the zone in which there are counterbalancing compression stresses, but it is possible to load so that the most important part is taken locally within the structure.

Figure 4 gives an example of a method of applying a load in a local zone already carrying stresses of the same sign. This is a plate on which studs are welded, fairly close together. Suppose now a spot between these studs is heated from both sides; the metal expands a little but is constrained by the rigid cold plate surrounding, so the hot metal upsets a little bit. On cooling, this region tends to contract but again is held by its rigid surroundings so the cold spot then contains residual tensile stresses.

Now slip yokes over the studs and pull in the direction of the arrows. The major part of this applied tensile load is localized in the metal between the studs where a fairly high tensile load already exists. To prove this experimentally it is necessary to attach extensometers with *very* short gage lengths. If a series of such are attached be-

*See also "Brittle Failure of Steel Structures — Factors of Importance", by M. E. Shank, *Metal Progress* for October 1954, p. 120.

tween the pins – say ten in all, end to end – one of them will record plastic deformation as soon as external load starts, but the others show elastic relaxation. In other words, a small amount of strictly localized plastic flow has relieved stresses in the neighborhood.

A longer gage length will only integrate these movements, and the *total* deformation is quite small – of the same magnitude as the elastic deformation occurring in the surrounding zone containing the residual compression stresses. If the pull on the yokes (external load) is increased, the plastic flow between the studs will occur in a larger mass of metal, but plastic deformation of macroscopic dimensions will be impossible without disturbing the outer zone with residual compression stresses. Thereupon further localization of the load is impossible.

From these considerations we conclude that:

1. Local loading can superimpose residual and load stresses.
2. Yield point is reached, *locally*, very quickly.
3. Deformations can be measured only over *very* short gage lengths.
4. No macroscopic changes can be recorded; plastic changes are of the same order of magnitude as the elastic deformation due to the residual stress.
5. Since localization of the load becomes impossible as soon as macroscopic yielding occurs, residual stress has no apparent influence on ultimate strength.

A second possibility for localizing the load is by the shape of the piece. If it has a crack, notch or any other physical discontinuity, any external load will produce higher stresses around these discontinuities than in other portions nearby. The result is the same as though the load were severely localized; the yield point at the discontinuity will be reached almost immediately, but again macroscopic yielding can only be recorded after the whole piece behaves plastically.

If the temperature is below the "critical temperature" for initiating a brittle crack, any residual stresses concentrated at a crack or notch might provoke a brittle fracture, even when a rather small external load is applied. This principle emphasizes the need for excellent workmanship to prevent any defects in welded joints.

Total loading is only possible in pieces free from defects. If such a metallic member contains residual stresses and it is loaded externally, properly instrumented to record stress versus strain, the departure from a straight-line relationship is earlier than though the piece were initially stress-free. Accurately determined, the stress-strain curve is curved from the start. If such a piece is then unloaded, it will be found on retest to act as though it were stress-free – that is to say, the stress-strain line is straight up to the yield point. The ultimate strength has not been influenced.

The exact mechanism of this behavior has been studied by special test pieces sketched in Fig. 5. Note that these are, in effect, stout yokes enclosing a rectangular test piece of reduced section. Residual compression stresses are separated from the residual tensile stresses by an air gap or slot. When the dimensions are properly proportioned, external loads can be applied at the ends of the assembly so the piece stressed in tension can be in the plastic range while the stresses in the compression legs remain in the elastic range. In this manner, we can study what happens in both zones during loading and unloading, and get some good ideas about what is called mechanical stress-relieving.

By this technique of mechanical stress-relief the engineer can relieve residual stresses at the expense of a little capacity for plastic deformability. This must usually be considered to be an improvement. The possibility that brittle fracture may be propagated is decreased and the resistance to corrosion is better.

It is obvious that mechanical stress-relieving must be done above the transition temperature.

Residual Stress and Fatigue

In practice, the effects of "local" loading arise in a structure containing defects (and one might say that no structure of any size or complexity can be free of them) on which external loads are applied. The harmful effect of these stress peaks on fatigue strength is well known. While residual stress may have some influence, it is the consensus of European students of the problem that they are completely masked by the harmful effects of physical discontinuities.

If a sound structure is submitted to an alternating load, it has been demonstrated that residual stresses are relieved during the early loading cycles.* The magnitude of this relief depends on the magnitude of the external load; the higher the load the more important the decrease in residual stress. Likewise, the most important fraction of the stress-relief occurs during the first few loading cycles; during subsequent alternations or fluctuations of stress some more of the residual

*Editor's Footnote – American studies of welded ships indicate that alternating loads are incapable of relieving dangerous residual stresses.

stress will be eliminated but its amount is a steadily smaller fraction.

From these same principles we conclude that although stress-relieving may be a justified operation on structures containing discontinuities, it is of no value if the structure is truly sound.

Elastic Stability

Much controversy exists on the influence of residual stresses on elastic recovery or stability. Of course when a piece contains residual stresses it also contains residual strains, and if they are unsymmetrical the piece will change shape or warp. It seems almost impossible to determine whether such change in shape, or any inelastic action, is due directly to the residual stresses or to prior distortion (straining) of the piece due to the same.

Corrosion

Residual stress has long been known to increase the tendency to corrosion. Corrosion cracking of brass cartridge cases is an instance. Stress-relief (thermal) is very good policy after heavy cold work.

Conclusions

The actual knowledge on residual stresses may be summarized as follows:

1. If the temperature is below the transition temperature of the material, residual stresses have an influence on the propagation of brittle fracture.

2. During static loading of a sound structure, residual stresses have an influence on the yield point, but not on the ultimate strength.

3. The fatigue strength of a *sound* structure is not affected by residual stresses.

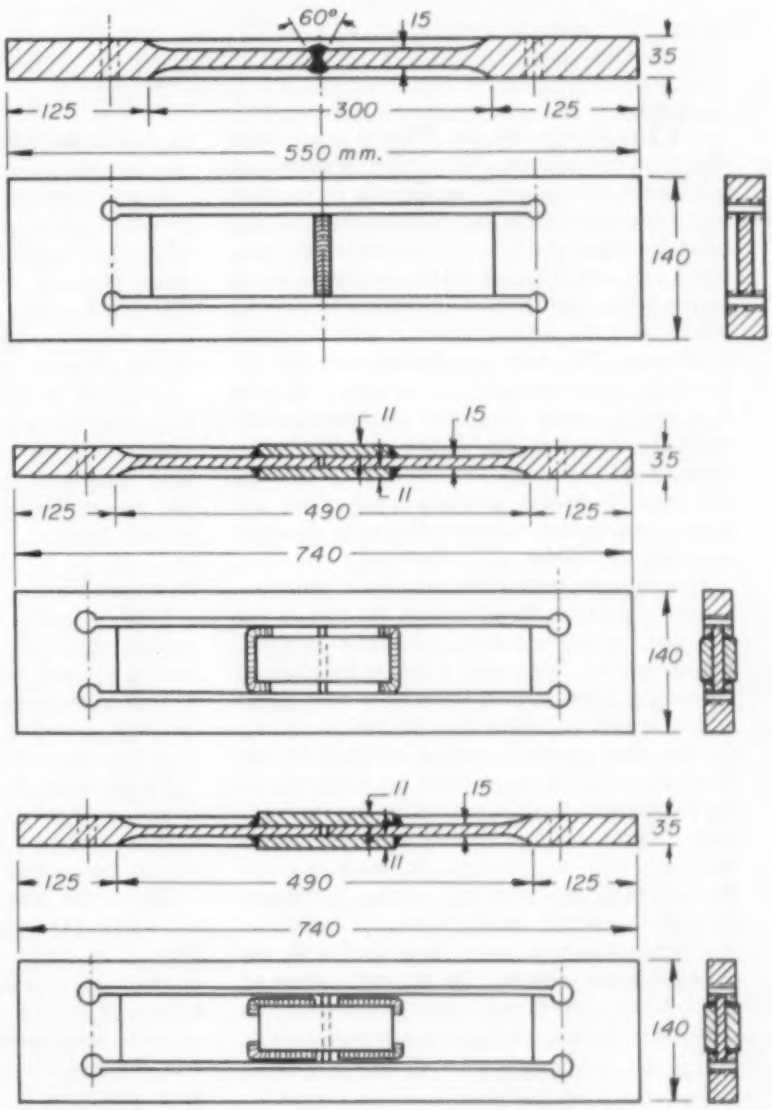
4. During static loading of a structure with faults (cracks or notches), residual stresses influence the fracture appearance if the temperature is below a critical value.

5. The influence of residual stresses on fatigue strength of a structure in which there are faults is masked by their effect as notches.

6. The role of residual stresses on elastic stability is not known.

7. Residual stresses are known to increase the tendency to corrosion.

Fig. 5 — Welded Test Pieces for the Study of Mechanical Stress-Relieving Wherein Reduced Sections Are Held by Stout Compression Yokes. Top is butt weld; middle is transverse weld; bottom is longitudinal weld. Dimensions are in mm.



A German View of Brittle Welded Structures

*By EDOUARD HOUDREMONT**

Tentative German standards specify steels for welded structures by impact strength at definite temperature. The author reviews the causes of brittleness in steels and describes the commercial means of manufacturing tough metal. He believes annealing of weldments – even local annealing of joints – will insure safe performance of a well-designed and honestly fabricated structure.

WELDMENTS are no different from other structural components; their design, material and fabrication plus erection are equally responsible for their serviceability. The design and fabrication must be adjusted to the properties of the material, and any change in these properties reacts on the design and processing. Steelmakers everywhere know that when a structure fails, the metal is at fault! This hasty conclusion may later be justified – in the minds of the accusers – because it is easy to select a material of higher quality without changing the design or fabrication methods. However, experience has taught that this may be neither possible, economical, nor even a satisfactory solution. The new structure may still be unsafe!

The ancients knew that iron has a tendency to brittle fracture; they notched the bars at the end and broke them with a hammer to prove their toughness. Since such a simple test showed differences between iron made by various methods, it is not surprising that the oldest and by far the most practical method adopted by students of metals is represented by the notched-bar impact test. It differentiates among materials with respect to deoxidation and de-nitration practices and to changes in microstructure through heat treatment, by varying the sharpness of the notch or the testing temperature. The nonaging steels were developed with the aid of this test method. The favorable effect of grain refinement through heat treatment was recognized in this way many, many years ago, as well as the influence of banded structure and nonmetallic inclusions.

It was therefore possible, as early as the mid-twenties when the welding technique was adopted in structural shops, that the metallurgist could place at the disposal of the designer a diversified spectrum of steels with graded sensitivity toward brittle fracture, as measured by the curves showing how their notched-bar impact varies with temperature. As shown by Fig. 1, the temperature for transition from low impact strength and its associated "brittle" or cleavage type of fracture to much higher impact strength and its associated "tough" or fibrous fracture extends from + 100° C. for the aged ingot iron to − 80° C. (− 110° F.) for a nonaging Izett steel very low in oxygen and nitrogen.

Thus, as brittle fractures began to appear in welded structures, not only did one possess a testing method which indicated any tendency to brittle fracture and differentiated among the available materials, but also a means of choosing from a number of steels in mass production.

Furthermore, it was quickly recognized that it was essential to limit the hardening of the heat-affected zone adjacent to the weld by limiting carbon content of the materials.

Despite the possession of a time-tested method of verifying the toughness of the constructional steel at its working temperature and a variety of excellent types on the market, some disastrous failures of welded structures occurred. Especially since the large number of breaks in welded Liberty ships, a number of novel testing methods were proposed (in addition to the weld-bend

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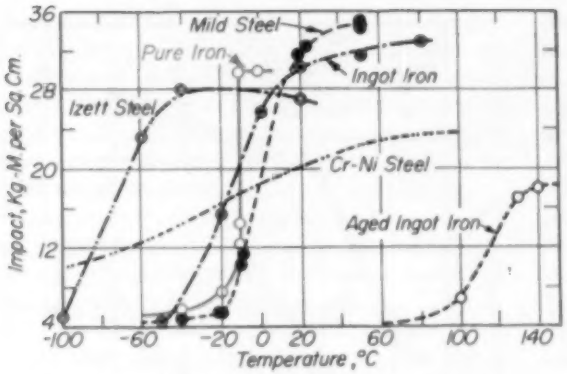


Fig. 1 – Typical Impact-Versus-Temperature Curves Showing How Transition of Fragile to Tough Condition Is Affected by Composition and Treatment. "Pure iron" has 0.35% total impurities. The Izett nonaging steel and the chromium-nickel steel are in the heat treated condition. Otherwise the samples are normalized

tests of Kinzel, Slogan, Tipper and others). A rather careful survey of the resulting data leads the present writer to the belief that all this testing has led to no other essential differentiation among variously produced and treated steels than could have been obtained with the notched-bar impact test. This points to the conclusion that all the testing methods probe into the constitution of the material in about the same way.

One other consideration needs to be mentioned before examining the causes of brittle fracture: Engineers have frequently overlooked the fact that scarcely any welded component exists whose stress patterns in service are completely known or can be discovered through stress measurements. By that same token, no testing method exists which can summarize, in the form of a *single* test value, the ability of a material to withstand the various stress conditions in each individual design and method of fabrication. Values obtained by mechanical testing are hardly ever characteristic physical properties but are data obtained under standardized testing conditions which can be transposed by the designer only empirically.

A Few Essential Considerations

Let us therefore make a brief survey of the constitution of our principal structural material – steel – essentially a complex of iron crystals with a little iron carbide, also crystalline.

It has been demonstrated that the body-centered alpha iron crystal has greater elastic elongation* in the [100] direction or cube face than in others, and it is believed that this indicates a lesser cohesion between atomic planes perpendicular to this [100] direction. When tension stresses are imposed in such a perpendicular (normal) direction, the distance between atom planes lengthens proportionally to the stress. This constitutes elastic deformation. But if the tension stresses are overpowering, too strong for the cohesive attraction, the crystal breaks or cleaves along the cube face. Cleavage along the cube face thus is associated with the crystal structure through a law of nature, and in order for it to appear requires only the presence of sufficiently high stress *normal* to the cleavage planes.

As a rule, plastic straining also takes place in a lattice which is strained elastically. Initiation of plastic deformation, in contrast to cleavage, requires a shear stress high enough to cause slip along definite, metallographically preferred planes. For slip, the shear stress must surpass a definite value known as the critical shear stress. Provided no points of weakness exist within the grains or in the grain boundaries, this critical shear stress is considerably lower at room temperature than the cleavage strength.

It appears essential that an elastic deformation be able to occur practically with the speed of sound, while the process of slip requires considerably longer time; likewise the speed of loading must be less than the speed of deformation, else brittle fracture will result. Plastic deformation through slip will commence the sooner and easier, the higher the shear stress. On the other hand, interferences (as by stranger atoms situated in dislocations or their vicinity, or precipitation in the slip planes) obstruct this process, decrease the velocity of slip, and increase the shear stress required to initiate and sustain slippage.

From these brief considerations it follows that three factors decisively affect the behavior of a material under mechanical stress:

1. The nature of the stress condition,
2. The rate of stressing, and
3. The temperature.

Stress Condition – It is a principle derived from elementary mechanics that shear stresses, necessary for plastic deformation by slip, are related to the differences between the principal stresses resolved along the X, Y, and Z axes in space. With strict unidimensional stress (pure tension or compression along the X-axis, for

*That is, stretch per unit tensile stress.

example) the stresses along Y and Z are zero, and the shear stress depends upon the existing tension or compression. Thus, we are accustomed to think that the yield point in an ordinary tensile test is related uniquely to the critical shear stress. Upon triaxial loading, on the other hand, with the three principal stresses equal, as in hydrostatic pressure on a spherical vessel, no shear stress whatever exists. Therefore, no slip can occur and only the possibility of cleavage at sufficiently high stress remains.

Now, one can in theory separate every triaxial stress condition into a purely hydrostatic component from which no shear stress results and a component whose principal stresses are not alike and from which shear stresses arise. Upon such conditions, the behavior of a ferrite crystal will depend on whether the stress perpendicular to the cube faces attains a sufficiently high level to cause cleavage, or whether the shear stress resulting from the other component becomes sufficiently great to initiate plastic deformation. These relationships are important since the stresses impressed upon a structure together with the residual stresses† existing within the material always cause conditions of multiaxial stress, especially wherever notches, section changes, weld joints, or discontinuities of any type are present in the structure.

What these matters mean to engineers may be apparent from the following: As against the theoretical cohesive strength of about 700,000 psi. computed from the atomic cohesive forces for high-purity iron, values ranging between 70,000 and 175,000 psi. at — 300° F. have been determined in the laboratory, decreasing with increasing grain size in accordance with metallurgical experience at atmospheric temperatures. The difference between the empirical and the theoretical values probably is due to the fact that anisotropy and lattice imperfections are neglected in the theoretical computations. However, it is evident that the normal (perpendicular) stress required for cleavage failure lies substantially higher than the critical shear stress required to initiate plastic deformation, which at room temperature lies at about 14,000 psi. for polycrystalline pure iron. This is fortunate. Iron

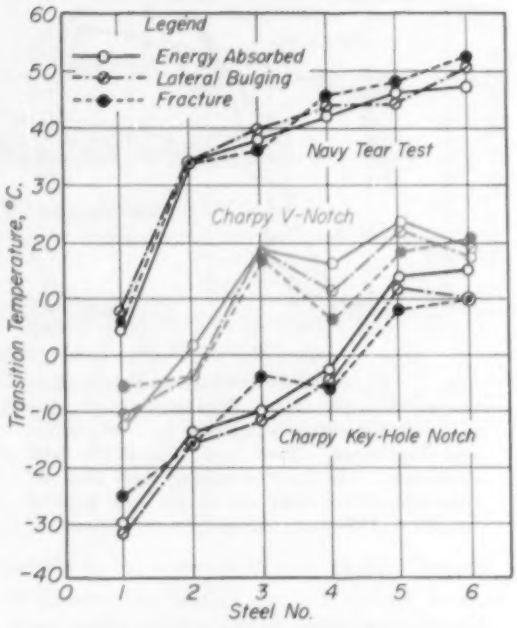


Fig. 2 — Transition Temperatures for Tough-to-Brittle Fracture Are in Same Relationship for Six Constructional Steels Even Though Determined by Three Different Test Methods. Middle set of values (in color) are results of Charpy V-notch tests. Top curves represent Navy tear tests; bottom curves are Charpy key-hole notch tests

starts to move plastically under uniaxial loads at any speed less than catastrophic, and if overstressed breaks only after considerable deformation. If the circumstances were otherwise†, the fracture would be of a cleavage type, without much if any advance warning by change of shape from plastic flow.

Rate of Stressing — It was mentioned above that plastic deformation requires more time than elastic straining and that its beginning and course also depend on the rate of stressing. This lag by the plastic deformation means that critical cleavage strength may be reached before plastic deformation can follow the rise of stress; in this event cleavage fractures occur during high rates of loading. With corresponding stress conditions or low temperatures, elastic strain may cause cleavage failures even before any plastic deformation begins.

Temperature — The speed with which dislocations within the metal can move — and, thereby, the speed of the process of slip — is dependent on the thermal motions of the atoms. Slip is therefore obstructed at decreasing temperatures, and the critical shear stress necessary

*See Professor Soete's discussion of residual stresses on p. 108 of this issue.

†For example, residual stresses, sharp notches, and other internal inhomogeneities may build up local triaxial hydrostatic stress components larger than the cleavage strength *before* the shear component reaches the necessary value to start plastic deformation.

to initiate slip is increased. Possibly the number of slip systems in an iron crystal may also decrease with falling temperature. The normal stress which leads to cleavage fracture increases less rapidly with decreasing temperature, so the appearance of cleavage failure is favored by decreasing temperature.

In summary, three considerations are equally important to the behavior of metal under stress in a structural component, and these are reflected in its behavior in acceptance tests:

A multiaxial stress condition prevents (or at least delays) the development of the shear stress required for slip deformation.

Through a *high rate of stressing*, the elastic straining of the lattice may lead to cleavage fracture before plastic deformation can begin. Stressing may also outstrip deformation.

With decreasing *temperature*, the plastic deformation is rendered more difficult so that the elastic straining and the resulting cleavage may get the upper hand.

Useful Test Methods

When we examine the various methods of testing a metal for its tendency toward cleavage fracture, we find that they always revert to a combination of the factors just mentioned, which are to a certain extent mutually interchangeable. It then becomes apparent that a tendency to cleavage fracture can only be discovered by a test program which varies at least one of the conditions systematically. Furthermore, one must always bear in mind that in all the conventional testing methods the critical shear stress and the critical normal stress (as well as changes they undergo during plastic deformation) are not measured directly. They enter only indirectly into the experimental evidence. Since it always is the same conditions which lead to brittle fracture in the end – that is, conditions which influence the race between elastic straining of the lattice and slip deformation – it is not surprising that all the diverse testing methods classify metals in the same order, at least qualitatively. Some examples in point from a recent investigation by N. Christensen and B. Augland are reproduced in Fig. 2. Where single differences arise, they are essentially due to the variability of the testing methods and their different reactions to segregations and inclusions, as discussed in some detail later.

Since the fundamentals which determine the appearance of the cleavage fracture can be qualitatively revealed by testing methods which differ considerably, the responsible engineer should have confidence in his decisions reached with their help. He is able to interpret the behavior of a material and the influences which affect it on the basis of these fundamentals, and direct development through a *single* testing method. For that reason, the following discussion will cite the evidence of only one test, namely, the curve showing notched-bar impact versus temperature.

The Transition Temperature

Even high-purity iron is subject to brittle fracture on account of its crystal structure. This was demonstrated anew by recent studies of pure, laboratory-produced iron by investigators at the National Physical Laboratory in England.* The sharp transition from the high to the low level shown in the colored curve in Fig. 1 depends on the fact that, with the prevailing stress distribution and rate of stressing, only a slight decrease in temperature suffices to switch from slip deformation to cleavage fracture.

As shown by all other curves in Fig. 1, the position of this transition can be changed from -100 to $+100^{\circ}$ C. by various steel production methods and differences in composition and heat treatment. The individual alloying elements affect the cleavage tendency of pure iron in quite various manners and ways. Elements such as carbon and nitrogen, which dissolve interstitially and thereby create a lattice strain, prefer positions near and in the dislocations in the strained lattice; they hinder the movement of dislocations and therefore increase the critical shear stress, while their influence on the critical normal stress remains less. Thus, the total effect is an increased tendency to brittle fracture. Possession of a definite yield point or tendency to harden with age (the latter, as is well known, strongly promotes brittle fracture) is related to this interaction between carbon and nitrogen on the one hand and the dislocations on the other.

The effect of a low content of oxygen is different: It collects preferentially in the grain boundaries of pure iron without developing microscopic particles, yet with so great a disruption of the intergranular cohesion that the grain boundaries tear apart even before plastic deformation begins – that is, the transition is displaced to higher temperatures. Thus the British investigators found that pure iron with

*See article by N. P. Allen, W. P. Rees, B. E. Hopkins and H. R. Tipler, *Journal* of the Iron and Steel Institute, 1953, p. 108.

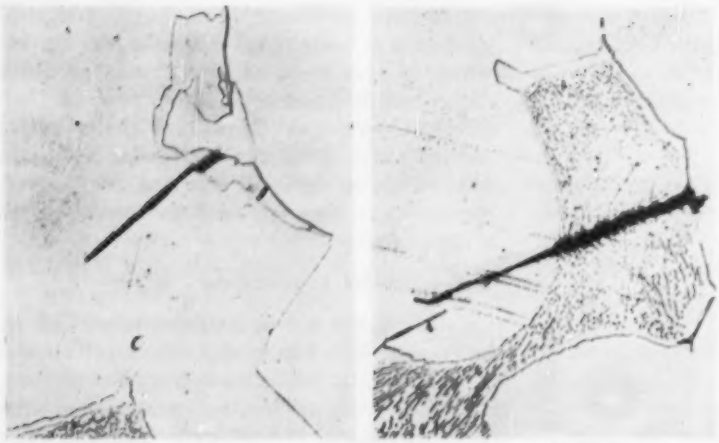


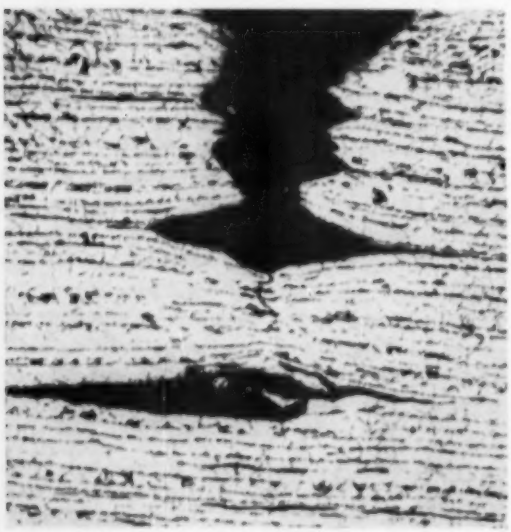
Fig. 3 – Incipient Cracks Starting From Grain-Boundary Carbide (Left) and From Pearlite in Pure Iron With 0.05% C. Water quenched sample at left; furnace cooled sample at right. 250 ×. (Allen, Rees, Hopkins and Tipler, Journal *of the Iron and Steel Institute, 1953, p. 108.)*

0.0010% oxygen has a sharp transition temperature of — 10° C.; if it had 0.0037% oxygen the transition temperature was + 18° C.; if 0.0046% oxygen it was 87° C. A similar impairment at the grain boundaries is caused by sulphur.

The influence of elements which form substitutional solid solutions with iron has not yet been fully explained. Individual elements such as silicon seem to obstruct deformation by slip even at room temperatures. The same holds true for other elements. Phosphorus as high as 0.10% has no harmful effect on the fracture of pure iron, laboratory refined. It is generally recognized as damaging to ingot iron, where it is associated with other elements in concentrations of about 0.05%. The influence of metallic elements in pure iron is not so definite and, as a rule, acts only in higher amounts.

A special influence on the tendency to cleavage fracture is exerted by heterogeneous inclusions. Thus, the influence of carbon on the transition temperature depends on how it is distributed as carbide in the microstructure. Thus, the transition temperature of pure iron in air-cooled condition is about — 15° C. If 0.05% carbon is added to this material, its transition temperature is — 55° C. if water quenched, + 70° C. if air cooled, and + 120° C. if furnace cooled. Carbon in slowly cooled iron-carbon alloys is precipitated as grain-boundary carbide which ruptures upon deformation and thereby facilitates cleavage fracture. (See Fig. 3.) Water quenching, on the other hand, refines the structure and has a favorable effect.

Fig. 4 – Fracture Path in an Impact Test of a Strongly Fibrous Steel Containing 0.11% Carbon and 1.34% Manganese. 50 ×. (Matton-Sjoberg, Journal *of the West of Scotland Iron and Steel Institute, 1952, p. 180)*



Since the fine-grained condition is considerably less sensitive to cleavage fractures, all fabrication measures which refine the grain and disperse inclusions in the ferrite will improve the steel. Regardless of any heat treatment, such a grain refinement is also attained by combining the nitrogen with aluminum or vanadium (which also decreases the aging tendency). Finely dispersed heterogeneous inclusions cause a gradual rather than an abrupt transition from high to low-level impact, as can be seen from the curves in Fig. 1.

Experience with wrought iron has told us that elongated inclusions deflect cleavage fractures and thereby promote the deformation or fibrous fracture. This ancient knowledge is utilized in the modern steel plant in various ways.

For instance, if high-quality spring steel is banded, due to inclusions, or mild steel is made fibrous by rolling in the transformation range of

Table I – Tentative German Standards for Steels for Large Welded Structures*

Grade	% P (Max.)	% S (Max.)	Kind (a)	Deoxidation	Impact Test			
					Specimen†	Condition	Temperature	Strength
"A" Quality, Suitable for Low Welding and Service Stresses								
St 37 A	0.08	0.05	B B	Note (b)	—	—	—	—
St 42 A	0.08	0.05	B B	Note (b)	—	—	—	—
"B" Quality, Suitable for Medium Welding and Service Stresses								
St 34 B	0.04	0.05	OH or W	Note (b)	DVM-F	Aged	+ 20° C.	8 kg-m.
St 37 B	0.06	0.05	OH or W	Note (b)				
St 42 B	0.06	0.05	OH or W	Note (b)				
"C" Quality, Suitable for High Welding and Service Stresses								
St 34 C	0.05	0.05	OH or W	Note (c)	DVM	Unaged	0° C.	7 kg-m.
St 37 C	0.05	0.05	OH or W	Note (c)				
St 42 C	0.05	0.05	OH or W	Note (c)				
St 44 C	0.05	0.05	OH or W	Note (c)	Sharp Notch	Unaged	0° C.	3.5 kg-m.
St 52 C	0.05	0.05	OH or W	Note (c)				
"D" Quality, (Nonaging), Suitable for High Welding and Service Stresses								
St 37 D	0.045	0.040	OH	Special	DVM	Aged	+ 20° C.	5 kg-m.
St 42 D	0.045	0.040	OH	Special	Sharp or Notch	Unaged	– 20° C.	3.5 kg-m.
St 52 D	0.045	0.040	OH	Special				

*Thicknesses should be limited according to Table II and tendency toward brittle fracture.

†10×10-mm. bars. DVM-F has round bottom notch, 8 mm. wide at top, 4 mm. deep. DVM has key-hole notch 3 mm. deep, 2 mm. diameter hole at bottom.

(a) B B = basic bessemer or Thomas steel; OH = openhearth or Martin steel; W is special bessemer steel; if unkilled, nitrogen is 0.008% max.; if killed, nitrogen is 0.010% max.

(b) As agreed upon; unkilled, semikilled or killed. (c) Killed with silicon and aluminum.

temperature, a fibering influence shifts the notched-bar impact-versus-temperature curve to lower temperature when the metal is tested perpendicular to the fiber. In general, such a fiber structure corresponds to a multiplicity of layers of different materials, as is shown by the fracture path in the notched-bar specimen in Fig. 4. Overall, the maximum impact strength is lowered but the transition from fibrous to cleavage failure is more gradual. It should be remembered, however, that the laminated structure is poorer when loaded perpendicularly to the fiber.

This influence of banding, segregation or inclusions should be given special consideration when viewing the scatter of results from a series of impact tests.

The German Steel Industry's Recommendations

This brief survey shows that the tendency to cleavage fracture can be influenced to a great extent, first, by reducing the harmful contaminants, such as phosphorus and nitrogen, and second, by adding elements which combine with the harmful elements, reduce the aging tendency, and refine the grain. Furthermore, we can produce a fine, uniform dispersion of the heterogeneous inclusions, especially the carbides and nitrides, as well as refine the grain, through alloying and heat treatment.

Since it is possible to reduce the tendency to cleavage fracture to a considerable degree, the reader might conclude that the general problem of brittle fractures and the special problems concerning welded structures, have been solved – if not completely, yet to a major extent, as far as the materials are concerned. (Obviously, it cannot be solved perfectly, since the cleavage fracture is a consequence of the crystal structure of the alpha iron and is determined by nature.)

In this connection, the commercial aspect, the dollars and cents, must not be disregarded. All of the available measures for reducing the tendency to cleavage fracture influence the cost of producing the steel. One cannot say, simply, "Let us use only a high-quality, nonaging, fine-grained steel for all welded structures." This presents no economical solution of the problem of brittle fractures.

The bare fact is that the use of steel in tonnage for welded structures must always revert to the simplest materials – ordinary openhearth or converter steel. This economic fact demands that

Table II – Tentative Classification of Welded Structures, Service Stresses and Welding Practices

Welded Structures
Group 1: Simple structures with smooth section changes and thin sections.
Group 2: Structures with well-designed section changes without accumulation of weld beads in thicker sections.
Group 3: Accumulation of weld beads in thinner sections.
Group 4: Accumulation of weld beads and unfavorable section changes in thick sections.
Service Stresses
Group 1: Static stresses acting above room temperature.
Group 2: Static stresses at low temperatures.
Group 3: Impact stresses above room temperature.
Group 4: Impact stresses down to low temperatures.
Welding Practices
Group 1: Welding without precautions.
Group 2: Welding after preheating.
Group 3: Local annealing after welding.
Group 4: Postannealing of the entire weldment.

the structural design be properly adapted to welding, or that measures be taken after welding to alleviate any bad effects of the welding operations, or both. To help the designer, the German steel industry has proposed in agreement with the International Institute of Welding that steels of all specifications up to St52 (structural steel with a minimum ultimate strength of 52 kg. per sq.cm. or 74,000 psi.) be classified into four different groups in accordance with their tendency to brittle fracture, and that the high-quality groups have a guaranteed minimum notched-bar impact strength at a definite temperature. This classification is shown in Table I. Furthermore, to match this classification of the materials, it is proposed to classify the steel structures in accordance with the service stresses of the structure and the welding methods in the fabricators' shop. (See Table II.) The engineer can then assign a definite value to each of the variables in order to recommend a specific steel for the machine or structure.

Welding Stresses

In the interests of the welding techniques and economy, it seems pertinent in conclusion to refer once more to the question of welding stresses. In the other, time-honored fabrication

*See Professor Soete's discussion of this problem beginning on p. 108.

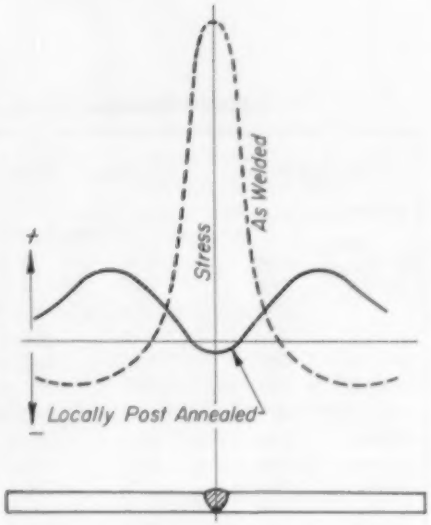


Fig. 5 – Approximate Influence of Local Annealing on Residual Stress, Longitudinal to a Welded Seam

processes, the object of each finishing operation is to deliver structural components with minimum residual stress (to avoid failure through the superposition of residual stresses and service stresses). This aim has been modified by the welding engineers. The result is that the designer provides for service loads which would vary from 14,000 to 17,000 psi. (or at the most 21,500 psi.) in forged, rolled, or riveted steel components, yet these might be supplemented in weldments, as a result of the welding operation, by residual stresses which are near the yield strength. In fact, stress determinations in welded components have revealed peak stresses reaching 85,000 to 115,000 psi. in and beside the weld seam. If one considers that these stresses reach a level which can initiate cleavage failure, he realizes the glaring discrepancy between the stresses created through welding and the stresses on which the designer based his calculations. It would seem appropriate to state that except for gross errors in the design, nearly all troubles with welded structures have been caused by this discrepancy.*

Since a postwelding anneal is often technically and economically impossible, increased attention should be given the long recognized method of lowering the locked-up stresses by local preheating or local postannealing. The effect of local annealing on the stress distribution alongside a weld is shown by Fig. 5.

On the basis of such considerations as the above, the author for about 20 years has assumed

(*Continued on page 200*)

Advances in Welding in Britain

*By E. BISHOP**

Fig. 1 – Weld-Fabricated School Building in Norfolk

The adoption of wartime gains in welding is everywhere evident in Britain. Much interest has been stirred by new concepts in the design of welded structures and the improvement of weldability of high-tensile steels. Among other advances are electrodes that give crack-free deposits, a stitch welder having double the usual welding speed, and the use of twin-cored electrodes to speed manual arc welding.

WELDING and allied techniques came of age during the war years, when many outstanding technological problems were solved by compulsion and many feats of engineering were performed which in less critical times would have been deemed quite impossible. Now, almost ten years later, we can look back and realize that although welding technology has continued to advance rapidly, we have been largely occupied in reaping for peacetime industry the benefits of experience gained under wartime conditions.

High-Strength Weldable Steels

The Bailey bridge was an early solution to two problems, namely, engineering design for welded fabrication, and structural steels for easy weldability. Design for welding has continued to exercise the minds of structural engineers and there have been numerous interesting developments in various directions. The "plastic theory of design", developed at Cambridge University under Prof. J. F. Baker, is of very considerable interest and value, in that it leads to drastic reductions in the weight of structural steelwork. A school building designed on the basis of this theory has recently been completed at Hunstanton, Norfolk. Its skeleton structure consisted of a series of welded double-story portal frames of 20 and 24-ft. spans, located on 10-ft. centers, main columns and roof beams of 9 x 4-in. sections and the floor beams of 12 x 5-in. sections, all of ordinary structural steel. A ground-floor view is shown in Fig. 1; the facing frames are structural members, acting as jigs and stiffeners for the main frames.

Up to 40% can be saved in the weight of steel for single-story factory buildings by using welded tubular steel members in place of bolted or riveted hot rolled sections. Figure 2 shows a factory designed in this way; the photograph was taken 14 weeks after erection was started.

The advantages of weight saving and more rational design which welding gives to structural engineering can be further accentuated by the use of high-tensile, low-alloy steel. The search after such steels of good weldability has continued without respite. The molybdenum-boron steel "Fortiweld" has already been mentioned in *Metal Progress* for January 1954, p. 101. This

*Assistant to the Director of Research, B.S.A. (Birmingham Small Arms) Group Research Center, Sheffield, England.

should perhaps be considered as a special steel rather than a structural steel. Rolled sections are, however, being made and used in conventional low-alloy steels with yield or proof stress up to 56,000 psi., and others tried experimentally up to 67,000 psi. (a Ni-Cr-Mo alloy steel developed by the British Welding Research Association) and even up to 80,000 psi. These higher tensile steels are being carefully investigated from the point of view of balancing carbon and alloy contents to give optimum weldability. Above a yield or proof stress of about 65,000 psi. the low-hydrogen type of electrode with lime-fluorspar or lime-titania coating must be used, since hardenability must necessarily be high to produce this strength level in structural sections in the hot rolled or normalized and tempered conditions.

It has been found that Ni-Cr-V alloy steels develop a substantially higher yield-to-ultimate ratio than Ni-Cr-Mo alloy steels in the hot rolled or normalized (untempered) condition. The possibility is now being seriously considered of hardening and tempering structural sections to reduce alloy content and hardenability for a given strength level and thus improve weldability. Provided the mills can handle the heat treatment economically, there appears to be no obstacle to producing a structural steel with 70,000-psi. yield stress which can be welded at the site using general-purpose electrodes without fear of the hardened zone cracking.

Welding in Shipyards

In British shipyards, 80 to 90% of new construction is now of welded design. The first shipyard to be laid down in Great Britain for nearly 30 years, opened at Newport in South Wales in November 1953, has been designed exclusively for welded prefabrication and will eventually be used for ships up to 45,000 tons. However, after the Adams Lecture delivered to the 1953 Annual Meeting of the American Welding Society at Cleveland by R. B. Shepheard, director of the London Shipbuilding Conference, on "Aspects of Welding Research in British Merchant Shipbuilding", little else need be said to indicate that this application of welding is being fully exploited in Britain. Collaboration between Britain and the U.S. has been particularly close and fruitful in this field, especially on the problems associated with brittle fracture in ship plate.

Of great interest from many aspects is the launching of a 72-ft. yacht of 45 tons displacement, the "Morag Mhor," with an all-welded aluminum alloy hull (Fig. 3). It was welded using the self-adjusting argon-shielded-arc process known to us as "Argonaut" (and as "Aircomatic" to the readers of *Metal Progress*) and was designed and constructed as an illustration of the possibilities of the material and the process.

The postwar years have brought a tremendous increase in Great Britain's output of power-plant and chemical equipment, particularly for the oil industry, both for use in this country and for export. Although multirun manual welding with pressure-vessel electrodes capable of yielding radiographically sound deposits is still commonly used, automatic welding using either the submerged-arc or continuous coated electrodes is coming more and more into use.

Fig. 2 — A Single-Story Factory Building of Welded Tubular Steel Construction

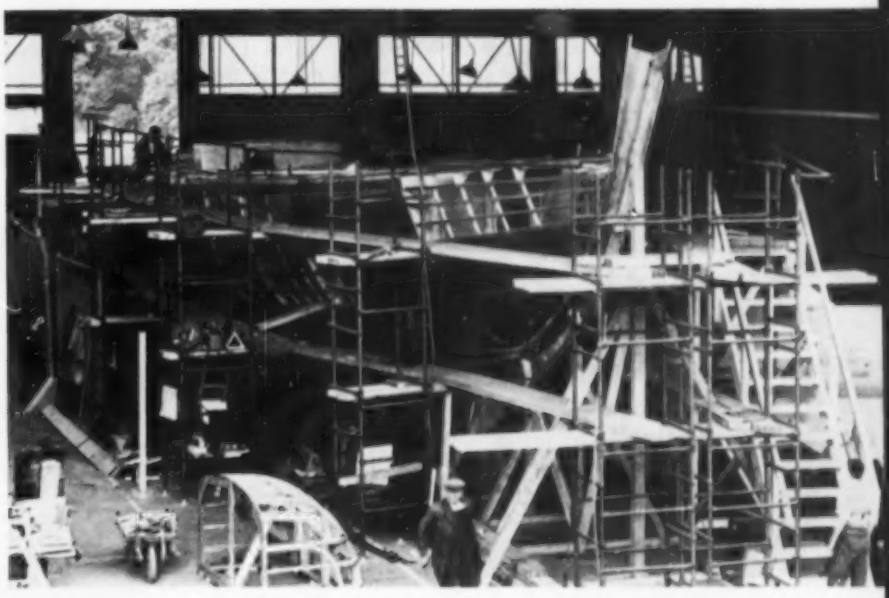


Fig. 3 – The Aluminum Hull Plates of the "Morag-Mhor" Were Welded by an Argon-Shielded-Arc Process Similar to "Aircomatic"

Austenitic Versus Partly Ferritic Welds

The difficulties of maintenance in chemical plants (and particularly atomic energy projects where safety precautions are of necessity carried to extremes) pose numerous problems to the metallurgist and welding engineer. Some mention of the peculiar metallurgical problems this can entail will no doubt interest metallurgical readers, especially as agreement has by no means been reached as to the best practical solution.

"Weld decay," due to the precipitation of chromium carbides in the vicinity of welds, is no longer a problem, though it is of interest to note that in Britain we prefer to include niobium (columbium) or titanium in weldable austenitic steels, whereas the American practice seems to rely more and more on a low carbon content.

The present problem is whether it is possible to obtain fully austenitic fusion welds free from microcracking. This problem was accentuated by the circumstance that metallurgists in the atomic energy projects selected a "standard" steel for corrosion resisting equipment containing 18% chromium, 13% nickel, and about 1% niobium. This is fully austenitic. Microcracking occurred in all joints made with electrodes which produced a fully austenitic weld deposit! The hypothesis was accordingly put forward that microcracking is an inherent defect in all ferrite-free weld metals; the practical remedy is to weld with an electrode of reduced (9%) nickel content.

It appears to be a general rule that small amounts of delta ferrite in the microstructure confer immunity from weld cracking. The disadvantage, however, is that this delta ferrite tends to transform at fairly rapid rates to the brittle sigma phase. Hence electrodes have been developed and are now commercially available which deposit weld metal with a "controlled ferrite content" – usually about 5%, sufficient to suppress cracking, but not so much as to embrittle the steel seriously should sigma phase occur.

There are signs that this problem is now nearing a logical solution. A satisfactory theory explaining why fully austenitic weld metal must *ipso facto* be susceptible to microcracking has not yet appeared. On the other hand at least two electrode manufacturers have made electrodes on an experimental scale that will deposit crack-free metals. At the same time, research is proceeding to ascertain the actual causes of the cracking in certain applications. In this direction the occurrence of a brittle intermetallic compound of iron, niobium and silicon has been proved in austenitic steels containing those elements.

Resistance Welding

Automobile body construction employs the most modern methods of resistance welding, and in keeping with its position as the world's largest exporter of cars, as well as Britain's largest export industry, the automobile industry is among the foremost in the development and application of

up-to-date automatic machinery. Figure 4 is a general view of the line of spot welding machines at the Luton factory of Vauxhall Motors Ltd. These machines are similar to those used in the United States, with the multiple spot welding electrodes all engaging the work simultaneously and capable of being energized either singly or successively in groups.

Stitch Welding – An interesting development in stitch welding machine design was disclosed about a year ago by the firm of New Process Welders Ltd. Stitch welding is especially useful where continuous resistance welded joints are required, in close quarters, where the disk electrodes of seam welding machines cannot enter. Up to now, the various mechanical means whereby the electrodes of a stitch welding machine can be repeatedly opened and closed have not permitted very high speeds; moreover, difficulties have arisen in synchronizing the power impulses with the electrode movement.

The new system is claimed to produce roughly twice the number of welds per minute – that is, up to 300 separate spots. It employs a diaphragm cylinder having a stroke up to about ⅜ in., which is friction-free and has a relatively small inertia (Fig. 5). This cylinder is double-operating and is controlled by a twin-solenoid magnetic valve. It can reach the high speeds required and can be accurately synchronized by electronic control devices to the welding pulses. It provides sufficient electrode movement for the work to move through the jaws; the machine is also provided with an orthodox piston-type cylinder of longer stroke, to open the electrode gap as required to insert or remove the work.

Electrode Coatings and Protective Gases

Turning to equipment for other welding processes, it must be confessed that Britain is still catching up to America in submerged-arc and inert-gas-shielded-arc welding. One British company specializing in automatic arc welding equipment is marketing machines for submerged arc as well as machines for the continuous coated electrodes. It is fortunate that the machines for both processes are handled by the same company (Fusarc) since this insures that the two can be considered side by side and each used for those applications to which it is best suited.

The use of the argon-arc process with consumable metal electrodes has already been mentioned in connection with the welding of the aluminum alloy vessel "Morag Mhor". Although argon-arc welding, manual and automatic, with tungsten or thoriated tungsten electrodes has been in some use in Britain, the later variants are relatively new. Although the high price of argon limits

Fig. 4 – Line of Spot Welding Machines for Automobile Doors at Vauxhall Motors Ltd.

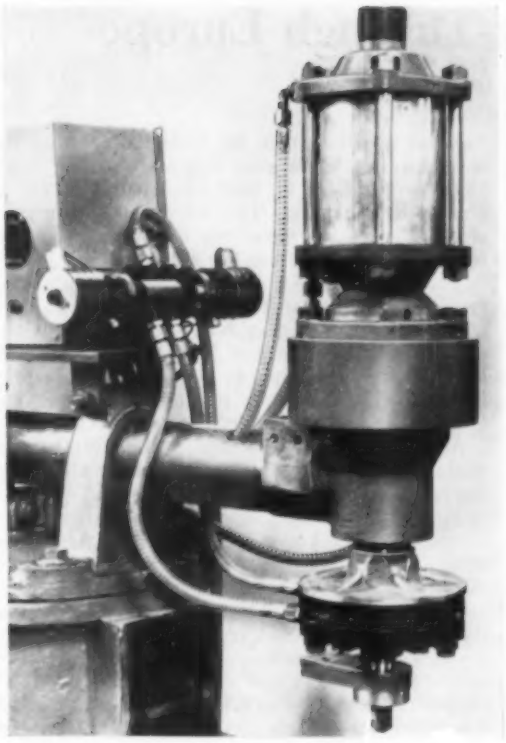


Fig. 5 – Stitch Welding Head Incorporates a Diaphragm Cylinder Which Doubles the Number of Welds Per Minute

the process at present to the more expensive metals, difficult to weld, such as aluminum alloys and stainless steel, a considerable and rapid expansion can be expected.

Despite the development of these various processes, the majority of fusion welding is and must be carried out by manual welding with coated electrodes. The versatility of this process, the low capital outlay for equipment, and above all the technical excellence of modern coated electrodes will insure their continued use for many years to come.

The rutile-type coated electrode continues to hold the field for general purposes, but the most interesting recent development is the rapid increase in the use of the low-hydrogen electrode with a basic coating already mentioned in connection with the welding of hardenable low-alloy steels. Hydrogen evolved from cooling weld metal apparently diffuses into the heat-affected zone and contributes in a major way to crack formation in that zone. This theory originated in this country during the second World War, and was fully substantiated when electrodes were developed from wnich hydrogen and water-containing constituents were rigidly excluded from the coating.

First used to replace the much more expensive austenitic electrodes in the welding of armor plate, these low-hydrogen electrodes are now widely used for many "difficult" welding jobs on alloy or medium-carbon steels. Alloy weld metals of high tensile strength made by introducing suitable alloys into the coating, are now in common use.

Twin-Cored Electrodes – From time to time various methods have been suggested for speeding up the process of manual arc welding. An interesting technique which has now come into use, following several years of extensive experiment, is the twin-cored coated electrode. This has two core wires, each of which is separately supplied with current from a two-phase transformer, the two phases being at 90° to each other. As might be expected, the melting rate is doubled by this process; also, there is a gain in arc stability, owing to arcing from one wire to the other. Although this principle has been applied to automatic welding, its adaptation to manual arc welding is particularly advantageous. An electrode holder with two insulated conductors is, of course, necessary. Specially extruded twin-cored electrodes are made for the more popular types of coating, but are really unnecessary since two separate electrodes can just as easily be clipped together with expendable S-clips.

Conclusion

In a subject as extensive as welding it is difficult to avoid the impression of hopping from one topic to another, and never staying long enough on any one to do it justice. Moreover, welding, like so many other modern technologies, knows no national boundaries and new developments usually appear more or less simultaneously throughout the free world. The scope of this review clearly shows that we in Britain are alive to the modern possibilities of welding, and are applying them vigorously and successfully to the joint aims of strengthening our economy and improving our standard of living and that of our friends and neighbors.

Finally, the author wishes to express his thanks to R. N. Thompson who has kindly made available some photographs from the journal of which he is editor, namely *"Welding and Metal Fabrication"*, which has celebrated its coming of age this year.

A Nuclear Journey Through Europe*

By ALVIN M. WEINBERG

To a visitor from a U.S. atomic energy project the most striking characteristic of the European effort is its enthusiasm. The enthusiasm stems not only from novelty; it stems from the fact that nuclear energy is a more urgent economic possibility in Europe. Over and over I was told how fossil fuel reserves are dwindling. Nuclear energy is assumed to be the only available energy source in not so many years.

The technical direction is determined by the nonexistence of enriched uranium and by the preoccupation with power rather than weapons. The problem is simply to extract useful power as cheaply as possible from natural uranium; this makes heavy water a practically unique choice for moderator.

The Oslo Heavy Water Reactor conference was concerned primarily with what can be done with heavy water and natural uranium. There was much discussion about the cost of heavy water — $90 per lb. in Norway. Its possibilities have already been described in American literature by the Commonwealth Edison-Public Service industrial power study group. [See *Metal Progress*, August 1953, p. 102.]

There were representatives from 19 different European, Asian and American countries, but none from the U.S.S.R. or its satellites. Among the most interesting was the Yugoslav, Dr. Dedijer, who told me of their research laboratory near Belgrade; it is being used not only for nuclear energy research but also as a focal point for the scientific enlightenment of the entire country. I got the impression that nothing was being spared to make the laboratory as excellent as Yugoslavia could afford.

Dr. K. Wirtz was the only delegate from West Germany. He told of plans for a 1500-kw. isotope-producing, graphite-moderated, natural uranium research reactor very much like the one at Oak Ridge, to be constructed when they receive permission from the occupying authorities.

After the Oslo conference ended I visited the atomic energy establishments in Europe and England, being everywhere received with utmost hospitality. What I found was certainly impressive.

The Joint Norwegian-Dutch Nuclear Energy Research Establishment (JENER) is located about 20 miles from Oslo. The 200-kw. reactor, moderated and cooled with heavy water much like the Argonne CP-3, has been running satisfactorily for over a year. The laboratory is working on neutron diffraction and spectroscopy, and general reactor physics. The Norwegians are planning to build a 25,000-kw. high-pressure reactor, contained in a spherical pressure vessel. The time schedule is indefinite.

The Swedish establishment is in northwest Stockholm. A 250-kw. heavy water reactor is at the bottom of a 90-ft. shaft sunk in solid granite. The workmanship on the reactor seemed superb. The Swedes seemed to take the matter of putting the reactor in an artificial cave very much in their stride since a fair share of their important industry is already underground. The Swedes, like everyone else in Europe, are vigorously devising schemes for extracting uranium from low-grade shales.

The proposed Swiss reactor is the most advanced type now under way in continental Europe. It is much like the Canadian NRX reactor except the coolant is heavy instead of light water. In Switzerland, perhaps more than in the other countries, the atomic energy work is a partnership between the government and the equipment manufacturers.

As the source of a sizable portion of the free world's uranium supply, Belgium has received special technical assistance from the U.S. and the U.K. in the field of atomic energy, and they are actively planning a 2000-kw. graphite-natural uranium reactor — again much like the one at Oak Ridge or the British BEPO.

Of the continental western countries, France has the most elaborate setup, now led by Francis Perrin, a well-known theoretical physicist. There are two laboratories, the old one at Fort Chatillón on the rim of Paris, and a magnificent new one at Saclay, about 20 miles from the city. There is a heavy water machine at Chatillón, recently modified to operate at 125 kw. Saclay has a much more ambitious nitrogen-cooled reactor (moderated with heavy water) designed to operate at 1000 kw. It seeks to solve the formidable problem of recirculating nitrogen at moderate pressure in a leakproof system. The reactor ran successfully for a short time early in 1954.

The Harwell establishment in England suggests Oak Ridge or Argonne. The British program is concerned mainly with building a large reactor, carbon dioxide cooled, for producing both plutonium and power (about 50,000 kw.). Seemingly, there is little concern about whether the electricity would be produced economically, or even whether the high-pressure gas is a valid coolant. Since the British possess plutonium, and have a uranium enriching diffusion plant, the developmental directions available are practically as varied as those which are available to us in America.

The essential lesson which our American atomic energy effort can learn from our Europan friends is that while we have more money in total, and more money per scientist, we seem to have less time to think, to plan, to consider. I could not help being struck with the quiet, scholarly, thorough approach toward big technology which certainly will bear fruit in future European developments and which we ought to cultivate in order to temper our own tendency toward technological flamboyance.

Thanks to those designers who have brought reactor devices within the reach of our universities, we in the National Laboratories and in heavy nuclear technology can look forward to a fruitful collaboration with our university research centers.

*Verbatim excerpts from article in *Bulletin of the Atomic Scientists* for June 1954. Dr. Weinberg is research director, Oak Ridge National Laboratory.

French Steelmaking Progress in 1954

*By G. HUSSON**

Optical pyrometers are being attached to converters and the blast (air plus oxygen and steam) regulated so melt is cool until just before the end of the blow. Openhearth research in France is centered on gas movements, combustion, and the control of sulphur from high-sulphur fuel oil.

A YEAR AGO in the January issue of *Metal Progress*, I described the recent European developments in Thomas (basic bessemer) steelmaking. Because this process plays an important role in Western Europe by virtue of the nature of the ores found there, current improvements have been the biggest news to steelmakers ever since the last War. The year 1954 saw continued development in the Thomas process and I intend to describe the principal results obtained in the year since my last report.

At the same time, of course, Europeans have an obvious interest in the Martin (openhearth) process since it is preponderant in Great Britain and is responsible for 60% of Germany's production, 30% of France's and 15% of Belgium's. Particularly in France, successful studies on the Thomas process have permitted steelmen to put greater efforts recently into openhearth research which the relatively more urgent converter problems had pushed into second priority immediately after the War.

Improvement in the Thomas Process – First I will say something about the mechanical properties of Thomas steel with low metalloid (S, P, and N_2) content – the so-called BTM steels†.

My 1954 article described a simple method of blowing steel with a blast of variable oxygen content, controlled by a special flowmeter designed by the staff of IRSID and described in *Revue de Métallurgie* for January and February 1954. By this means we can get a nitrogen content no higher than normal openhearth steel (0.005 to 0.007%) with less than 0.035% sulphur and 0.035% phosphorus. The process dispenses with the steam jets or oxygen otherwise used to drive the nitrogen down to a low content. A fair tonnage of ingots produced by this process have been made into wire and deep drawing sheets.

The Thomas BTM steel is fully as good as openhearth steel as far as wiredrawing is concerned. It is also fully as good as openhearth steel sheet for extra deep drawing, and it is generally satisfactory for a "super-extra" deep drawing grade, but it does fall somewhat short of openhearth steel for the most severe requirements.

Recent French work has done much to reveal the exact conditions of nitrogen solution during blowing. The heat developed during the blow appears unquestionably to be the essential factor. The final nitrogen content is lower, the lower the final temperature and the longer it is delayed. Cooling additions and oxygen injections should be timed so as to keep the charge as cool as possible right up to the end of the blast when it may be brought up to the necessary casting temperature. This schedule gives the best quality of metal containing the least nitrogen. Cooling the charge with an excess quantity of slow-melting lime is to be avoided.

End Point – A two-color pyrometer mounted on the converter bottom and sighted at the charge through one of the tuyeres has been used to study systematically the evolution of heat during the process in the above-mentioned re-

*Head of the Steelmaking Department at IRSID (French Iron & Steel Cooperative Research Institute, St. Germain-en-Laye, France).

†BTM steels refer to steels "a basse teneurs en metalloides", that is, low-metalloid steels.

search. Whether this instrument can be used to advantage in industry remains to be seen.

Kurlbaum's method of measuring flame temperatures, wherein a pyrometer is aimed into the flame and across it onto a standard lamp, is also being studied. (At least in the dephosphorization stage the flame temperature is related to the bath temperature.) The apparatus used is the same used by IRSID to determine the end point in the Thomas process by variations in the opacity of the flame as described by J. Galey, P. Leroy and M. Denis to the French Metallurgical Society in October 1953. Incidentally, this apparatus is used commercially for controlling the end of the blow. Half the Thomas converters in France and Belgium now have it installed, and it is used not only in blowing with straight air, but also in mixtures of air, oxygen and steam. With mixtures of air and oxygen without steam which produce heavy fume it indicates the proper end point to the blast with a precision that can't be matched by a workman's eye.

We at IRSID hope to apply the method to acid-lined bessemer converters in either England or America, there being none in France.

Collection of Red Fume – The use of oxygen in a steelworks – whether for combustion or refining in an openhearth, enrichment of converter blast, blowing with pure oxygen, or pre-refining of pig iron in a ladle – produces large quantities of red fumes composed of iron oxide. The electron microscope shows the constituent particles to be very fine (for the most part less than 0.1 micron in diameter). Because of their extremely fine dispersion, the obnoxious fumes form opaque clouds even when present in small amounts, and must be precipitated.

The fineness of the particles makes the job difficult. During 1954 IRSID tried out a de la Fourniere apparatus for collecting dusts from refining pig in the ladle. The apparatus (patented in France, No. 1136.128 – 620.429 – 50.479) consists of a dry dust collector followed by a water tower with a Venturi exit tube for atomizing the water. The pilot arrangement installed in one plant in Western France has given complete satisfaction, for it collects more than 98% of the fume given off above the ladle, even though it is a little bit smaller than desired for an industrial unit. The same procedure can undoubtedly be used on openhearth furnaces where oxygen is injected. It would seem that it can also be used in principle on converters using a blast of commercially pure oxygen into the top (as at Linz-Donawitz in Austria) where the fume problem is a particularly difficult one, although it must be conceded that the considerable volume of gas to be handled and the large dimensions of the Austrian equipment render the problem more difficult.

Transactions of the American Institute of Mining & Metallurgical Engineers, 1941 and 1943.

Openhearth Furnaces

Research into openhearth steelmaking is moving back into its own, now that the more urgent problems of the Thomas process have been handled. It takes two principal lines – *(a)* physicochemical study of the refining reactions and *(b)* combustion and heat transfer.

Refining conditions in a Martin furnace are different in French practice in comparison with American practice. Since the Thomas process has been so well developed in Western Europe, and it produces an adequate quantity of low-phosphorus metal, our Martin openhearth charges never exceed 30% pig whether it be molten (the usual practice at integrated steelworks) or solid. Under these conditions, even with phosphorus-bearing pig, dephosphorization is no problem. Reduction of silicon is a small matter since French pig has little silicon to start with. On the other hand, desulphurization is a major problem in furnaces fired with fuel oil, since nearly all our supply comes from the Middle East and contains 3% sulphur. For this reason, gas-fired furnaces (using either mixed coke oven and blast furnace gasses or producer gas) of which there are a good number, are better adapted to the manufacture of high-quality steels. As a result, current research programs are directed toward sulphurization of the steel by the flame.

Another series of experiments is aimed at evaluating the effects of basicity on the oxidizing potential of the slag. The first results have confirmed in the steelworks what Fetters, Taylor and Chipman* found in the laboratory, namely that at constant carbon, a given oxygen content in the metal corresponds to a higher iron content in the slag, if the slag is strongly basic, than though it had 14 or 15% SiO_2. These tests are to be continued in the steel plants.

Combustion and Heat Exchange – Since 1950, a systematic study of the radiation of luminous flames has been carried on in an experimental furnace of semi-industrial size at the Royal Steel works at Ijmuiden, Netherlands, by an international study group representing various British, French, Dutch, Swedish, and Belgian organizations, and, recently, the U.S.A.

(*Continued on page* 202)

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Properties combined in nickel-containing alloys contribute, for instance, to the efficiency of many components in the widely used DoALL grinders . . . both standard and special. Parts that must combine a high degree of wear resistance plus ready machinability, for example, are cast in alloy irons containing 1.50 to 2.00% nickel.

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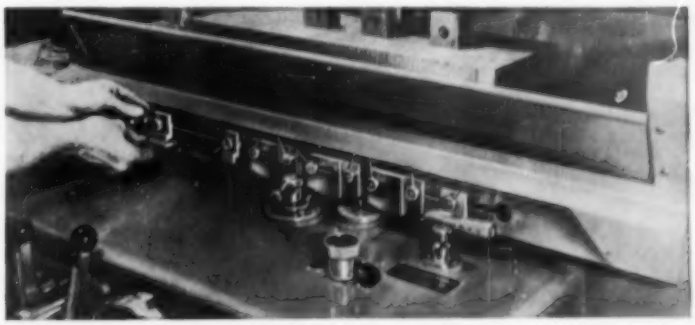

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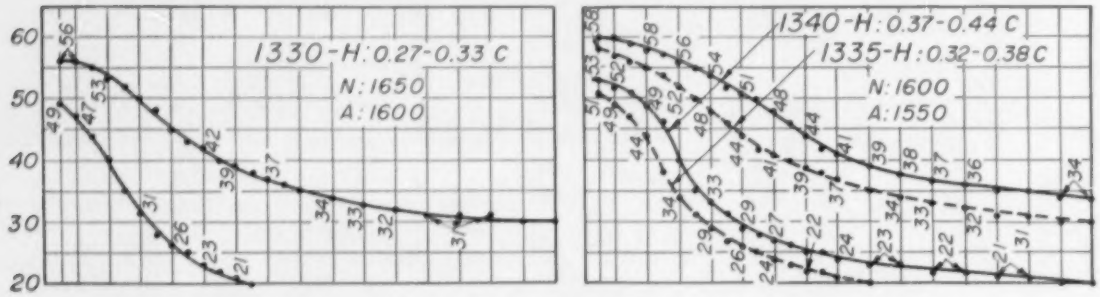
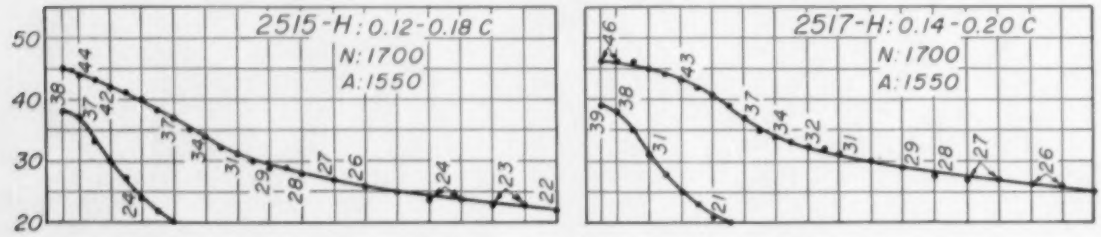
A.I.S.I. list of February 1954.

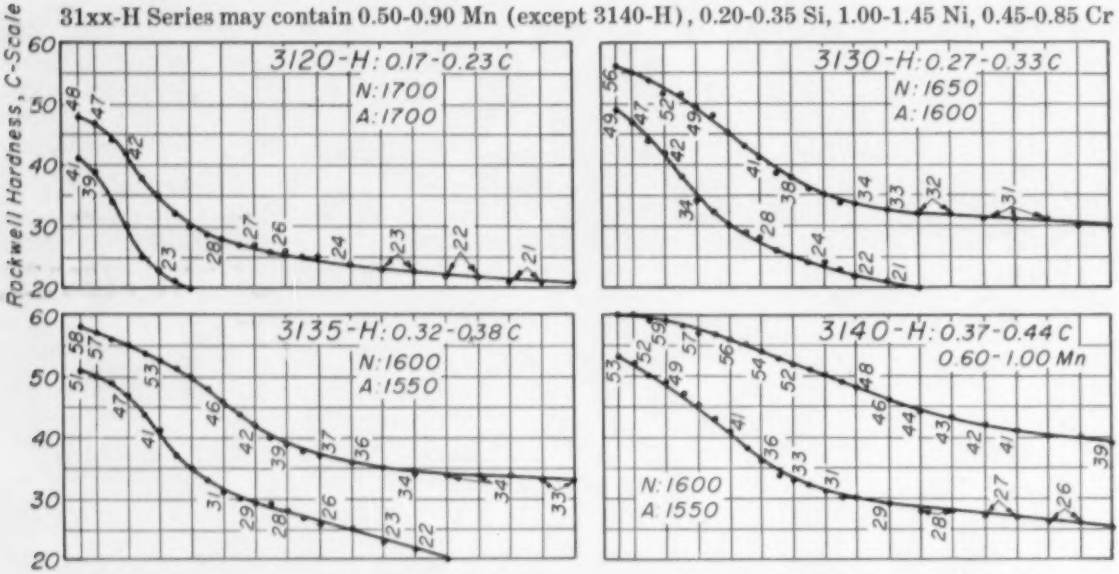
13xx-H Series may contain 1.45-2.05 Mn, 0.20-0.35 Si



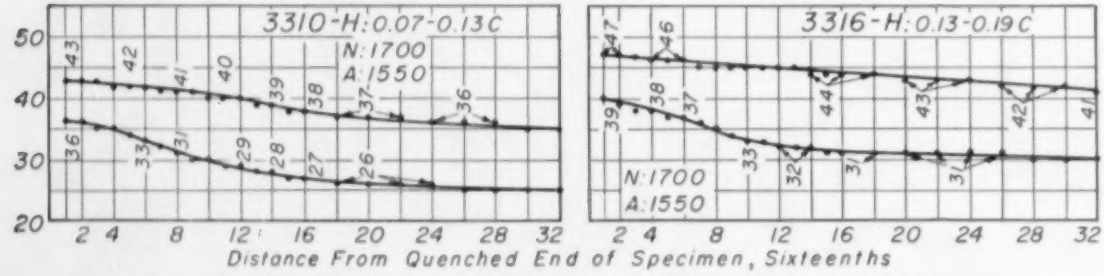
25xx-H Series may contain 0.30-0.70 Mn, 0.20-0.35 Si, and 4.70-5.30 Ni



31xx-H Series may contain 0.50-0.90 Mn (except 3140-H), 0.20-0.35 Si, 1.00-1.45 Ni, 0.45-0.85 Cr

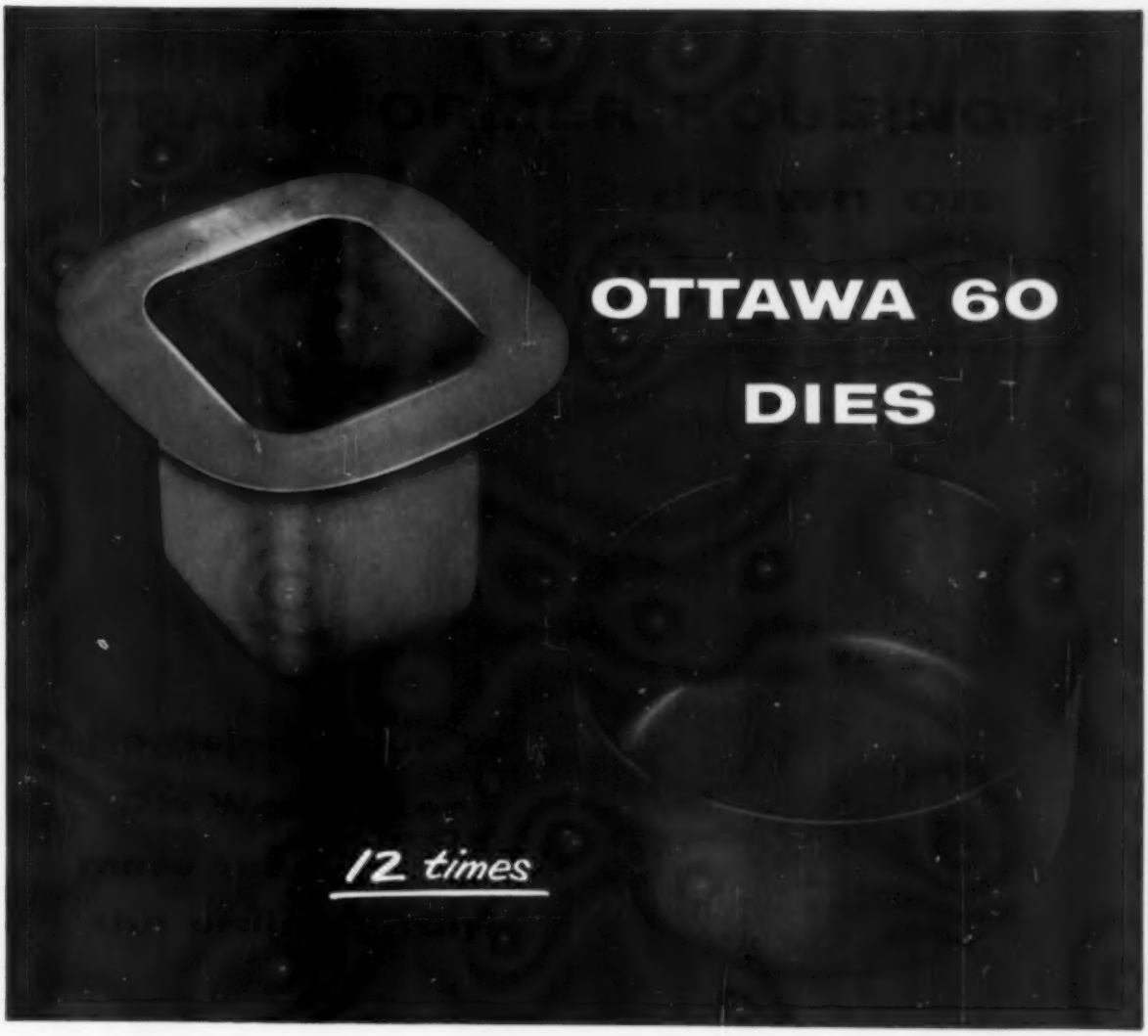


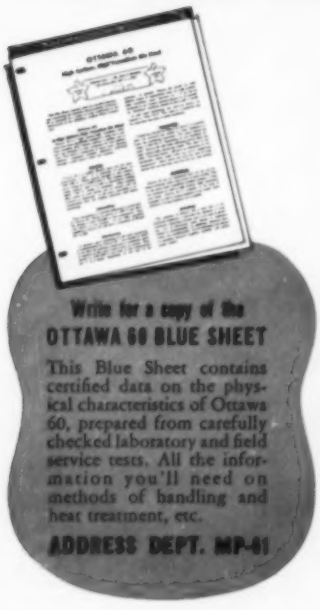
33xx-H Series may contain 0.30-0.70 Mn, 0.20-0.35 Si, 3.20-3.80 Ni, and 1.30-1.80 Cr



N means normalizing temperature for forged or rolled material; A means austenitizing temperature (both as recommended by S.A.E.).

Hardness limits are specified in Rockwell C-scale units (no fractions) and can be scaled from the plotted points where not labeled at even sixteenths.





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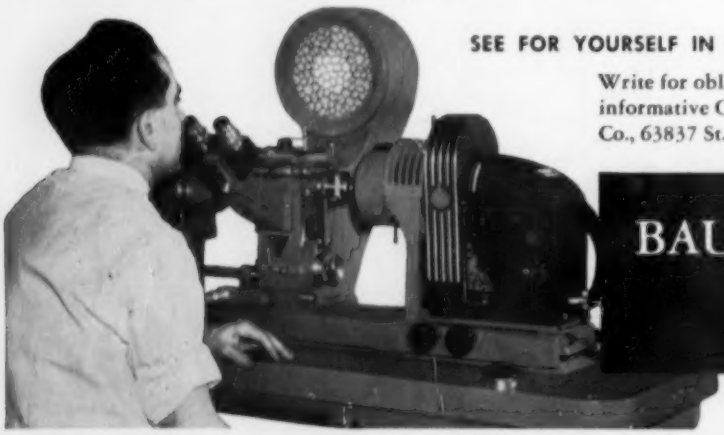

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Successful Manufacture and Use of All-Austenitic Welding Electrodes

*By EGON KAUHAUSEN and H. A. VOGELS**

Evidence is presented for the belief that cracks of all kinds, however named, in austenitic welds are due to grain-boundary inclusions. Crack-free welds, heavy and light, all austenitic, are in long, severe service. Electrodes are made of clean 16-13 Cr-Ni-Cb steel, under special electric furnace practice. Deoxidizers may sometimes need to be added to the basic lime-fluorspar coatings. Design and construction should also minimize residual stresses.

As POINTED OUT in the article in *Metal Progress* a year ago (January 1954, p. 116), the constantly increasing temperatures and pressures for chemical and power plants have surpassed the capabilities of the chromium-molybdenum and chromium-molybdenum-vanadium steels, rather low in total alloy content, used so successfully in German-built equipment. That article described boilers, superheaters and auxiliaries for a steam plant operating at 610° C. (1130° F.) and 160 atmospheres pressure – a plant which may be considered the first stage in current developments.

The fully austenitic, columbium-stabilized,† 16-13 chromium-nickel steel used for superheater tubes, valves and fittings in that installation

*Mr. Kauhausen is chief engineer of the welding electrode department, and Mr. Vogels is assistant director of research, Boehler Bros. Co., Duesseldorf-Oberkassel, Germany.

†Where columbium or Cb is used in this article, it means the mixture of columbium and tantalum which results from the reduction of the usual ores.

answered all the requirements as to high-temperature strength, corrosion, scaling resistance, and low tendency to embrittlement. A serious problem, however, arose in the welded joints; the customary austenitic welding electrodes could not be used. If we produced a matching austenitic structure in the weld metal, desirable for strength and corrosion resistance at and above 610° C. (1130° F.), and free from ferrite or delta constituent which might later change to the brittle sigma phase, we met with a serious number of microcracks in the central part of the weld and the fusion zone along its edges. After an intensive and long research, coated electrodes capable of avoiding these defects in the welds while retaining the desired qualities have been developed and marketed in Germany under the trade name "Fox Cn 16-13".

We will now describe this research in some detail and show a few examples of welds cut from equipment after long, successful and severe service.

Table I – Fully Austenitic Steels for Use Above 1130° F.

	16-13	16-13-Mo	16-13-Mo-V-N
Chemical Analysis			
C	0.10	0.10	0.10
Si	0.40	0.40	0.50
Mn	1.2	1.2	1.3
Cr	16.5	16.5	16.5
Ni	13.0	13.0	13.0
Mo	—	2.0	1.4
V	—	—	0.75
Cb	10 × C	10 × C	10 × C
N_2	—	—	0.10
Creep Strength (1% Elongation in 100,000 Hr.)*			
550° C. (1030° F.)	14,200	14,200	15,600
600° C. (1110° F.)	8500	9200	14,200
650° C. (1200° F.)	5700	7100	9900
700° C. (1290° F.)	3500	5000	—
Rupture Stress for Failure in 100,000 Hr.*			
550° C.	21,300	22,800	28,400
600° C.	12,100	12,800	18,500
650° C.	7800	8500	12,800
700° C.	5700	6400	—

*Quenched from austenitizing heat; 16-13-Mo-V-N is subsequently aged.

Steel for Electrodes – Even though we were able to produce faultless joints fairly early in our studies, these were fully austenitic welds in thin sections. Heavy, multipass welds were prone to crack. Likewise, we found that electrodes made from one heat would produce cracks, while electrodes from another heat of substantially the same analysis would make perfect joints. Finally, we had to work with three modifications of the 16-13-Cb austenitic steel base used for the pressure vessels, superheater tube loops, and for chemical synthesis, and each of these seemed to exert an individualistic influence on the cracking of welds made of matching analysis. Typical chemical analyses, creep strength and rupture stress for these three constructional steels are shown in Table I.

We realized that many competent welding engineers in all countries believe that a proper cure for weld cracks is to use electrodes which produce joints containing a limited amount of alpha (or delta) constituent. We believed this is inadmissable for the high-strength steels of Table I, especially the 16-13-Mo-V-N variety. These enable the steel consumer to reduce the wall thickness of tubes or to increase the operating pressures with unchanged wall thickness thereby attaining improved performance and economy – *provided* no danger exists that the welded joints become points of danger through sigma-phase embrittlement. In fact, the commercial use of these more highly alloyed steels was delayed because it appeared even more difficult to produce acceptable welded joints with electrodes of matching composition in these more highly alloyed steels than it had been with the 16-13-Cb steel shown in the first column of Table I, which had been used in the steam plant erected in 1951.

First we tried the obvious idea of melting heats to the composition given in the last column of Table I. Electrodes made from many such heats failed to make joints free from hot cracks and microcracks. The remaining possibility was to use core material of the simple 16-13-Cb analysis designed for uncoated electrodes, and introduce necessary alloying elements into the weld metal from the coating. However, this also was a disappointing approach. Finally, success was achieved when we used normal 16-13-Cb electrodes and made higher cobalt additions to the electrode coating which went into the weld metal and substituted for the carbide-forming elements molybdenum, tungsten and vanadium of the metal being welded.

Crack-free welds of high creep resistance and good tensile properties, made in this way, have the following typical composition: 0.09% C, 0.01%

S, 0.024% P, 0.31% Si, 2.56% Mn, 15.50% Cr, 11.85% Ni, 6.20% Co, 1.39% Cb.

Thus, the problem of welding the aforementioned steels was solved when sufficient quantities of usable core wire of the 16-13-Cb type could be melted. The analysis of the coating was determined.

We had to discover why the 16-13-Cb heats for electrodes were not reproducible. This applies to other products than welding electrodes. For example, we had observed that the tendency of 18-8, stabilized with either columbium or titanium, toward transverse intercrystalline fracture in the piercing mill is undoubtedly related to minor variations in the melting practice – especially degree of deoxidation.

Metallographic studies led us to conclude that – whatever the variations in the furnace may be – the conditions at the grain boundaries of the solid metal are of special importance to its forgeability. It is an elementary concept that during solidification the fusible remains are pushed ahead of the growing crystals of solid metal, and can eventually form an intercrystalline network. These grain-boundary films can be seen in some "tender" steels.

While the simplest of these films are silica glass, their composition and distribution are dependent on their viscosity and melting point – that is to say, on their chemical composition, which is directly related to the degree of deoxidation. Such grain-boundary films or inclusions weaken the cohesion of the grain boundaries.

If their melting point is lowered further through the entry of oxygen, or by reaction with oxygen remaining in the metal, then intercrystalline rupture during hot work is to be expected. These conditions are intensified by additional inclusions of oxidized impurities as well as by carbide precipitation in the grain boundaries.

The tendency toward the formation of microcracks, inherent in welds made from stabilized austenitic Cr-Ni welding rod, is directly parallel with the above phenomenon. Detailed metallographic examination of welds sensitive to hot cracks revealed an increased number of silicate inclusions; likewise, silica glass could be found along the primary grain boundaries in those welds which actually contained intercrystalline hot cracks.

The assumption that microcrack sensitivity originates in the metal used for electrodes will stand or fall according to the metallographic evidence: If preliminary tensile tests of electrode material show low ductility, laminated fracture, and harmful grain-boundary constituents, then similar test pieces of all-weld-metal made therefrom should show these same characteristics, and the welds will contain microcracks. Conversely, a clean electrode metal should (other conditions being equal) produce crack-free welds, and all-weld-metal of good ductility and fibrous fracture.

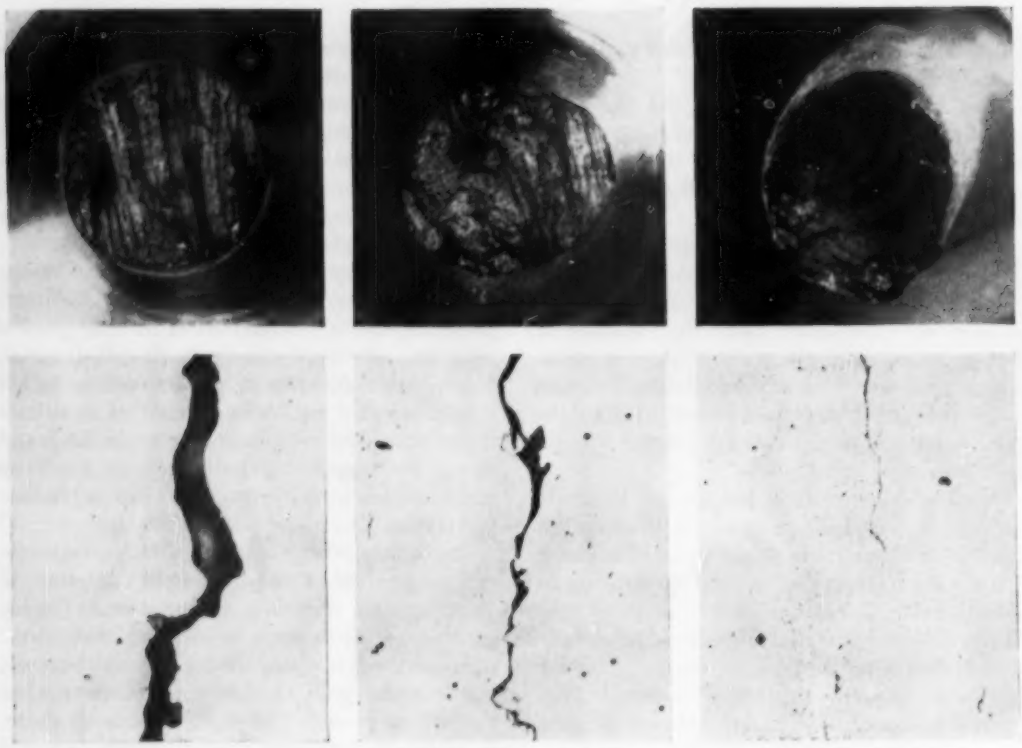
Evidence is provided by the following example: Three heats of 16-13-Cb, very similar in composition except Si and Cb, were made into electrode core wire and covered with the same basic lime coating containing some manganese. As shown in Table II, the analysis of the weld metal deposited from these electrodes showed no important change other than an increase in manganese, and this was uniform. Nevertheless, tensile specimens (all-weld-metal) varied widely in ductility and fracture appearance.

Table II – Chemical Analysis of Three Similar Heats, Yet of Widely Different Quality

Composition or Property*	Heat A		Heat B		Heat C	
	Electrode	Weld	Electrode	Weld	Electrode	Weld
Carbon	0.07	0.09	0.08	0.09	0.08	0.11
Silicon	0.08	0.10	0.18	0.14	0.28	0.18
Manganese	1.56	2.72	1.68	2.83	1.67	2.83
Chromium	17.10	16.70	17.35	16.60	17.40	16.55
Nickel	13.80	13.50	13.80	13.40	13.75	13.85
Molybdenum	0.23	0.29	0.23	0.22	0.22	0.22
Columbium	0.59	0.67	1.29	1.10	1.14	1.24
Yield strength		38,100 psi.		41,600		29,700
Tensile strength		59,000 psi.		65,000		72,500
Elongation		zero		19%		33.4%
Reduction of area		zero		24.2%		29.6%
Fracture		Woody		Moderately Woody		Slightly Woody

*Tensile specimens of 10 mm. diameter (0.394 in.); gage length of 50 mm. (2 in. approx.).

Metallographic examination of the tensile specimens at their deformed ends showed the following particulars: The frequency



Coarse Woody Fracture Thick Film; About 20 in the Section

Medium Woody Fracture Thin Film; About 10 in the Section

Fine-Grained Fracture Very Thin Film; Scarce; 2 to 3 in the Cross Section

Fig. 1 — Fracture of Tensile Specimens of Metal for Austenitic Electrodes at 3 Diameters, and Glassy Inclusions at Grain Boundaries at 1200 Diameters

of the observed silica grain-boundary films in the all-weld-metal from the various heats is inversely related to the elongation of the test pieces as listed in Table II, and directly related to the proportion of woody fracture.

Figure 1 shows that the core wire heats with the poorest welding quality have the thickest grain-boundary films and the most of them. The glassy films always appear like yellowish to brownish silicate under polarized light. At 1200 diameters even extremely fine branches of these films were visible down to a thickness of 0.00015 mm. (six millionths of an inch).

Thus the relationship is clear between the grain-boundary substance in the core wire (welding electrodes) and the microcrack sensitivity of the welds produced therewith. It is also confirmed by the concept, advanced by W. R. Apblett and W. S. Pellini in *Welding Journal* for February 1954, p. 89s, that the intercrystalline hot cracks form when the metal is cooling between the liquidus and solidus; the forces which arise during welding are high enough to open the still-liquid grain boundaries. During welding, espe-

Fig. 2 — Equilibrium Conditions in Iron-Chromium-Nickel Ternary System Wherein Fe = 75% and Cr + Ni = 25%. Approximate conditions for 18-8 Cr-Ni and for 16-13 Cr-Ni are shown by dotted verticals

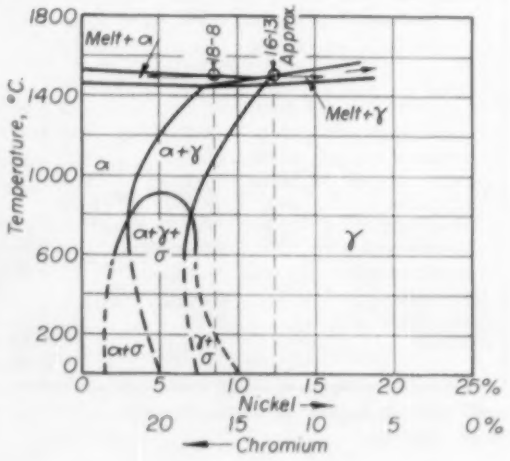


Fig. 3 – Tee Specimen, Tentative German Naval Standard Steel DIN 50 129. Medium carbon (0.30%) steel. Base 1.77 in. thick, 3.15 in. wide, 4.72 in. long; leg 0.47 in. thick, 3.94 in. high. About two-thirds natural size

Fig. 4 – Test Specimen Recommended by Kautz. Two short rounds, 1.57 in. diameter, 2.36 in. long, are laid side by side and welds run top and bottom. Material CK 35. Engraving about four-fifths natural size

cially upon welding over an end crater or depositing the next bead, fluid slags remaining from preceding runs and originating from the coating materials may enter these freshly formed grain-boundary cracks, and build up very coarse grain-boundary films.

Electrodes based on the 18-8 Cr-Ni combination usually deposit weld metal with 4 to 6% ferrite. Their freedom from microcracks in comparison with 16-13 Cr-Ni welds is due to differences in primary crystallization. This is indicated in Fig. 2. In the solidification of 18-8, crystals of chromium-rich solid solution first appear and the remaining melt is enriched in nickel. The opposite occurs in the solidification of 16-13, and chromium-rich material remains in the melt.

The greater solubility of oxygen in chromium-rich alloys is well known. Hence the oxidized components are precipitated early in solid form in 18-8 and are consequently enveloped by the growing crystallites, while the nickel-enriched mother liquor holds a relatively small proportion of nonmetallic inclusions. Hence the primary grain boundaries are relatively free of nonmetallics; they are well distributed through the matrix.

Solidification conditions of fully austenitic 16 Cr, 13 Ni alloys are the opposite. With falling temperature, the oxygen solubility of the chromium-rich melt decreases, so that an essential part of the oxidized impurities in the melt will lie in the grain boundaries of the solidified weld metal. The increased crack sensitivity of stable austenitic welding rod materials is due to the relationship between the hot cracking sensitivity and the grain-boundary substance, as explained in the preceding paragraphs.

These conditions are emphasized as the basic alloy becomes more complex by addition of molybdenum and vanadium, whose carbides preferably collect in the primary grain boundaries (especially in the weld metal).

Requirements for Austenitic Electrodes

Sulphur – It is of importance in this connection to bring up the sulphur content of weld metal. Apblett and Pellini mentioned in the paper already cited that 0.05% sulphur in austenitic Cr-Ni steel castings apparently leads to hot cracking. In our investigations it has become evident that core wire heats for welding electrodes can tolerate no more than 0.01% sulphur.

Grain Size – The relationships, furthermore, are undoubtedly affected by the primary grain size of the weld metal, a coarse grain being more sensitive to cracking since the surface tension acting on each individual crystallite is greater than in a fine-grained material.

Melting Practice – It follows from the preceding discussion that especial importance should be ascribed to the degree of deoxidation of austenitic Cr-Ni heats. This is related to the C-Si-Mn ratio, it being known that heats with higher carbon content from the start are better deoxidized than where the carbon has been boiled

Fig. 5 — Swiss BBC Test for Austenitic-Ferritic Welding. Fifteen plates 4.72 in. square, 0.16 to 0.20 in. thick, alternately of mild carbon steel and Type 347 (18-10 Cb) stainless, are bolted together and welds run in slots 0.39 in. wide, 0.05 in. deep. Natural size

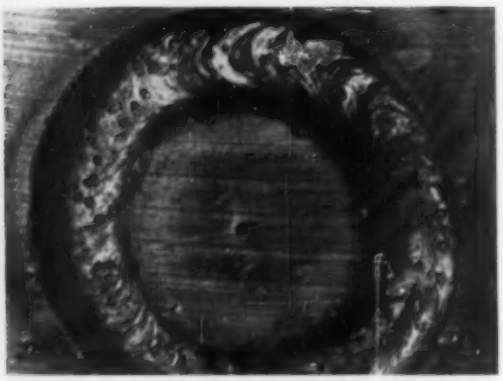


Fig. 6 — Test Piece Recommended by T. R. David, Jr. Test block of 18-10 Cb, 3.5 in square, 1 in. thick. A circular groove of 1 in. radius is cut, 60° Vee, 0.5 in. deep, and filled with weld metal. Natural size

down extensively. It is also well known that welding rod materials which yield a fully austenitic weld metal are easy to make in the higher carbon ranges — for example, about 0.20% C is appropriate for the 25-20 Cr-Ni and 18-8-6 Cr-Ni-Mn types.

O. R. Carpenter and N. S. Jessen have already called attention to this effect of carbon in their paper "Some Factors Controlling the Ductility of 25 Cr, 20 Ni Weld Deposits" in *Welding Journal* for December 1947, p. 727s. However, we require electrodes which will give welds in high-temperature equipment with relatively low carbon content, about 0.10% max., while stabilization with columbium or tantalum-columbium is desired for the sake of corrosion resistance. Should one attempt to stabilize higher carbon content, of the order of 0.20%, intermetallic compounds will appear in the grain boundaries, and are extremely dangerous on account of their brittleness.

C-Si-Mn Atomic Ratios — Our work led us to conclude that the proper electrode could not be specified by proportions of carbon to the deoxidizing elements silicon and manganese. Their percentages in the melt, as reported by the analytical chemist, merely indicate the degree of deoxidation.

In the course of our studies we made 30 columbium-stabilized 16-13 Cr-Ni heats. Carbon ranged from a minimum of 0.04 to a maximum of 0.095; silicon 0.16 to 0.71 (with the exception of one heat with 1.09%); manganese from 1.07 to 2.22%. These heats were fabricated into electrode wire and coated with various hydrogen-free mixtures. The individual melts were then evaluated by welding test pieces conforming to German, Swiss and American standards or recommended practices, as shown in Fig. 3 to 6.* Tendency to crack in the weld metal itself was the criterion — it was a "go or no go" test.

We thought it more suitable to study the chemical variations in electrode and weld metal by molecular percent, where the mole % of C+Si+Mn=100. For example, one of our successful electrodes analyzed 0.08% C, 0.47% Si and 1.33% Mn. Figuring these to millimoles per 100 g. by the respective formulas

$$1000\frac{C}{12}, \qquad 1000\frac{Si}{28}, \qquad 1000\frac{Mn}{54.9}$$

gives C=5.00, Si=16.79, Mn=24.23, a sum of 46.02. Mole % of these three, figured on 46.02=100, then comes to C=10.87, Si=36.48 and Mn=52.65. This analysis is shown at A on Fig. 7.

Successful weld metal using this electrode analyzed 0.10% C, 0.28% Si, and 2.93% Mn, which figured to mole % as follows: C=11.62, Si=13.94 and Mn=74.44. This analysis is shown at Point B on Fig. 8.

The results of our investigations are plotted in the triangular diagram showing mole percentages of C, Si, and Mn. (The basic composition was 16% Cr, 13% Ni.) There is no overlap of points figured from core wire analysis of the usable and the unusable heats. Heats were usable whenever

*A second test recommended by Mr. David, similar to Fig. 6, was also used. In this, four 1.75-in. square blocks made up the test block and they were joined by cross welds, 2.5 in. long. A circular grove, 2 in. diameter, was then cut into this block and welded full as in Fig. 6.

the molar ratio of Si to Mn amounts to 3.5, within the framework of the proper analysis limits. However, the scatter of the sound weld metal analyses within the triangular diagram shows that consistently useful heats are not obtainable by merely conforming to such an Si-Mn ratio, which is only an indication of a certain degree of deoxidation.

These considerations proved that through appropriate deoxidation methods, acceptable heats for core wire may be produced and fabricated to welding electrodes for fully austenitic welds in high-temperature equipment.

Thus, the investigation has shown that the quality of these special welding electrodes depends largely on the melting technique used in the production of the core wire heats. Our experience with the electric arc furnace indicates that it is extremely difficult to take all the metallurgical measures required to obtain a truly uniform melting practice – there are too many influencing factors.

Consequently, the producer of welding electrodes must segregate the heats by preliminary testing. For this we prefer the tensile test – especially the figure for elongation. We also build up a pad of weld metal sufficient for a tensile test piece and grade the electrode by the fracture appearance. The pad of weld metal is also studied under a microscope. No microcracks whatever are permitted to exist in welds from the really good core wire which is accepted.

The core wire from good heats, coated with simple basic lime-fluorspar coatings containing some manganese, produces electrodes which give good welded joints, free from microcracks, even on thick sections up to 4 in. We also check and confirm these findings by making the crack sensitivity tests shown in Fig. 3 to 6.

Coatings – Electrodes which produce blameless weld metal with simple coatings are classed as "good". Borderline heats may be classed as "usable" if a suitable change in the coating can suppress the microcracking tendency.

This coating technique aims for the after-deoxidation of the molten weld metal by adding proper agents from the coating. Such additions are not only Fe-Mn or manganese metal but also Fe-Si, Fe-Ta-Cb or zirconium alloys. Simultaneously, the weld metal may be grain refined under certain circumstances. Carpenter and Jessen had arrived at similar conclusions.

It must be pointed out that we achieved success in this effort only with basic lime coatings. We found repeatedly that additions of rutile (titanium dioxide) to such basic lime coatings or the use of rutile coatings with acceptable austenitic core wire gave poorer results.

Fig. 7 – Triaxial Diagram Showing Mole % of C, Mn and Si (All Figured to 100%) in 16-13-Cb Heats Intended for Welding Electrodes. Crosses represent conditions for heats which passed acceptance tests; circles represent unacceptable heats

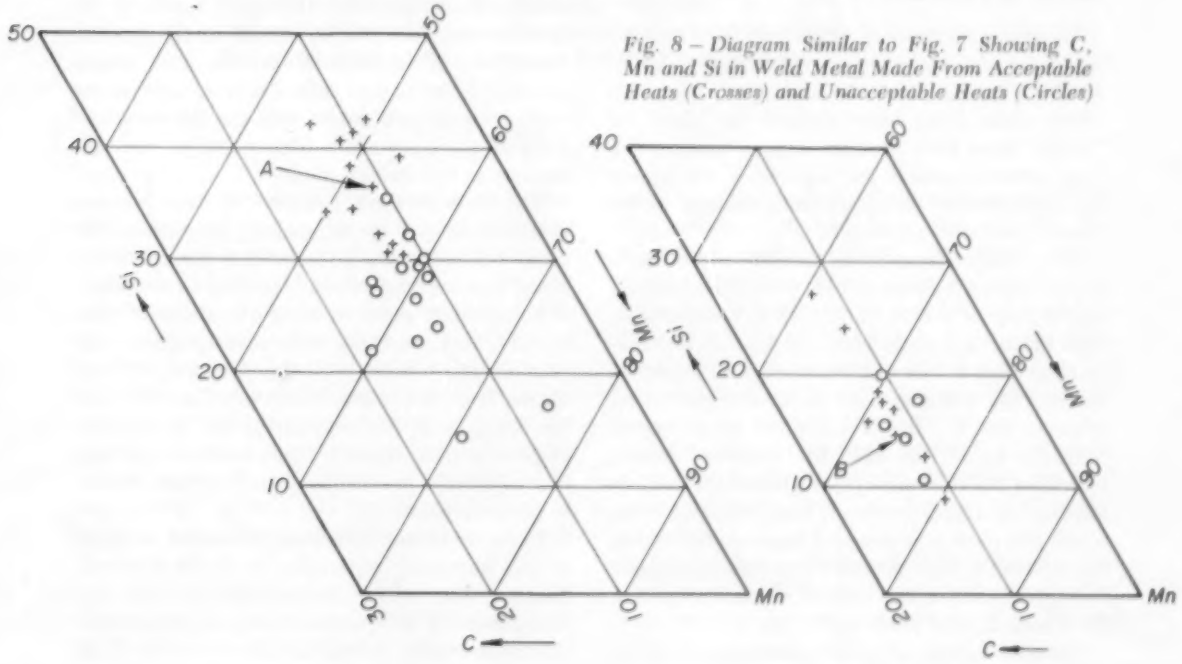


Fig. 8 – Diagram Similar to Fig. 7 Showing C, Mn and Si in Weld Metal Made From Acceptable Heats (Crosses) and Unacceptable Heats (Circles)

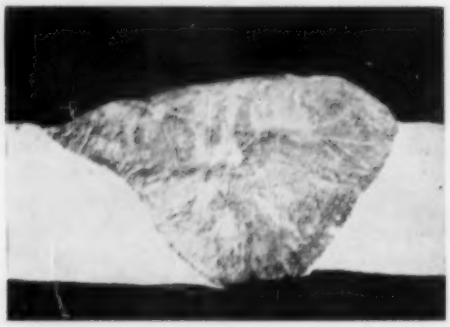


Fig. 9 – Welded Joint in Superheater Tube After 8000 Hr. Service at 610° C. Steam and 160 Atmospheres. 5×. All-austenitic weld (Fox CN 16-13)

Fig. 10 – Macrograph of Welded Joint in 16-13 Cr-Ni (Plus Mo, V, N) Tube With 0.64-in. Wall, Welded With Fox CN 16-13-6-Co Electrode. 3 ×. Sample taken from tube in high-temperature, high-pressure service in chemical synthesis. The weld is all austenite and absolutely sound

On the other hand, rutile-containing basic lime coatings may be used with the austenitic electrodes which produce welds with ferrite, especially with the high ferrite contents of 6 to 8%. Since the sulphur exerts great influence, the very minimum must be introduced through the coating. It is equally important to avoid traces of tin and arsenic.

Despite any modification that may be made in coating composition, core wire made from heats denoted as "unusable" from the preliminary tests cannot be fabricated into useful electrodes – at least according to our present knowledge.

Record of Experience

Welding electrodes produced in Germany under the above-mentioned restrictions, either of 16-13-Cb type or of 16-13-Co-Cb type, using core wires made from heats classed as "good" or "usable" have been used for welded construction with entire success in the welding of equipment for high-pressure chemical syntheses and in the hottest part of steam boilers.

Two samples from actual practice will be illustrated. Figure 9 shows a weld joint from a superheater loop of a 610° C. (1130° F.) boiler after 8000 hr. service. Such joints are considered especially critical in spite of the small wall thickness because the welding must be done in restrained positions and is difficult to control. As is evident from the figure, the weld has remained sound, free from any microcracks, in spite of the stresses imposed in actual service. The installation from which this piece was removed has accumulated in the meantime some 20,000 hr. of service without the appearance of any defects whatever even in thick-walled weld joints up to 2 in.

The macrograph (Fig. 10) shows a weld joint, absolutely microcrack-free, from 5-in. tubes with 0.64-in. wall, from a high-pressure installation for chemical synthesis, operating at 700 atm. and 550° C. (1020° F.).

In summary, it may be said that, in the opinion of the authors, *all* cracking phenomena in fully austenitic weld joints originate in conditions residing in the austenite grain boundaries of the welding rod, present to a greater or lesser extent in every heat of steel. (This includes coarse hot cracks, crater cracks, star-shaped cracks in the weld metal, root cracks, cracks in the heat-affected zone, under-bead cracks, and microcracks.) More or less severe defects arise in the weld joint in accordance with the thickness and kind of grain-boundary film, together with the stresses in the welded joint.

The fundamental solution of the problem therefore lies in a special melting practice and the correct deoxidation of the heats which are fabricated into welding rod and welding electrodes.

In order to avoid welding electrodes of poor quality, very searching tests must be given each heat in accordance with the program outlined above. It is furthermore absolutely necessary that the designers of the installations and the welding engineers who supervise the construction take every possible precaution to reduce the stresses in the weld joints.

These measures have been described in detail in the literature, especially by L. R. Poole in *Welding Journal* for August 1953, p. 403. His statements are in agreement with our experience presented briefly in this article.

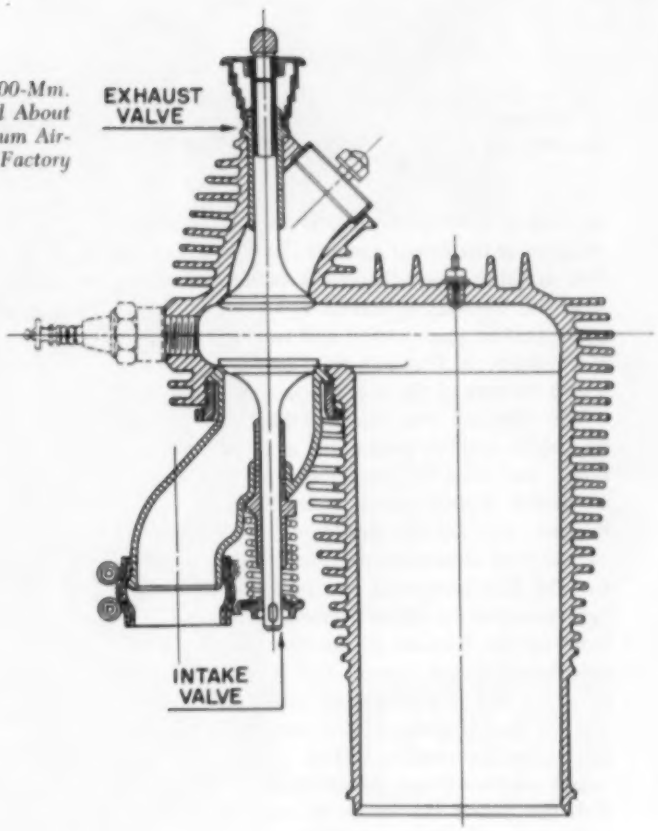


Fig. 1 – R.A.F. 1 A Cast Iron Cylinder of 100-Mm. Bore and 140-Mm. Stroke, Which Developed About 12 Hp., Was the Pattern for the First Aluminum Air-Cooled Cylinder Cast by the Royal Aircraft Factory

Origin of the Modern Air-Cooled Cylinder

*By S. D. HERON**

The idea of using aluminum instead of cast iron for the cylinders of air-cooled engines was an important milestone in aircraft development. It apparently originated with an Englishman who was inspired by an unknown Italian; their pioneering work is herewith belatedly acknowledged.

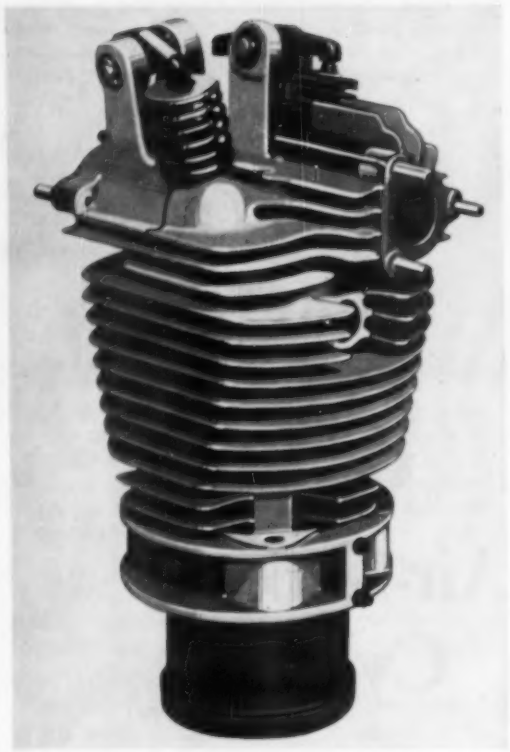
THE PURPOSE of this note is to record the origins of the modern type of air-cooled cylinder and to give credit to two forgotten individuals in England and Italy who, as far as the writer knows, have never received any public acknowledgment of their pioneering efforts. The modern air-cooled cylinder was originated for aircraft engines and has had its greatest use in this field. While the gas turbine is today the center of interest for aircraft propulsion, the piston engine is still of major importance for commercial aircraft. Of the piston engines in current aircraft operation, the great majority are air-cooled.

The modern type of air-cooled cylinder originated with the use of aluminum. It can be justly said to have started at the Royal Aircraft Factory (now Royal Aircraft Establishment or R.A.E.) in England in 1915 and from this ancestry has spread all over the world. The initial experimental work was immediately followed by an extensive research, design and development program under the direction of A. H. Gibson, F. M. Green and G. S. Wilkinson, and it was from this program that the air-cooled aircraft engine cylinder as we know it today has descended. It is the combination of high thermal conductivity with low density that makes aluminum the most attractive material to date for use in air-cooled cylinders.

While Gibson, Green and Wilkinson conducted and supervised the program with outstanding success, they did not originate the idea. Toward

*Consulting Engineer, Detroit.

Fig. 3 – 1916 Model R.A.F. 4 E Aluminum Cylinder of 105-Mm. Bore and 140-Mm. Stroke Similar to the Drawing of Fig. 2. It developed about 17 hp.



the end of 1915, Henry Percy Boot, chief engine designer at the Royal Aircraft Factory, suggested that an aluminum air-cooled cylinder be constructed; this was approved by Green, who then controlled all engineering and research activities at the Factory. This was prior to the appearance at the Factory of the first Hispano Suiza.

The Hispano was the first successful aircraft engine to employ aluminum as a cylinder material, and was the ancestor of a long line of successful *liquid*-cooled aircraft engines. The Hispano was not the first liquid-cooled aircraft engine with aluminum cylinders, but it certainly was the first successful one and an outstanding fighter engine in Allied service. Whether Green knew of the Hispano at the time of Boot's first experiment is not known, but it was not mentioned in the engine design group at this time and the first Hispano engine arrived at the Factory about the middle of 1916.

The engine design group became acquainted with the use of aluminum for water-cooled aircraft engine cylinders in late 1915. The writer, at the time a layout draftsman in the engine design group, subscribed to *The Horseless Age* (now *Automotive Industries*). This magazine in 1915 described the Chevrolet Brothers' racing cars, which had successfully performed that year at Indianapolis, were water-cooled, and had an aluminum cylinder block. The Chevrolet engine was described as having cast-in valve seat inserts – a feature copied in Boot's first cylinder.

In 1915 two eight-cylinder air-cooled Vee engines of Royal Aircraft Factory design were in production. Both had cast iron F-head (exhaust valve overhead) cylinders; the R.A.F. 1 A (shown in Fig. 1) was of 100-mm. bore and the R.A.F. 1 B of 105-mm. bore; both were of 140-mm. stroke. These engines were a slightly redesigned version of the French Renault, which was then in military use by both the French and the British. (It was also used then and earlier for military training in the United States.) The Renault had a detachable head with overhead exhaust valve and side intake valve; the R.A.F. cylinders had the same valve arrangement but the cylinder was in one piece with the intake valve in a detachable cage.

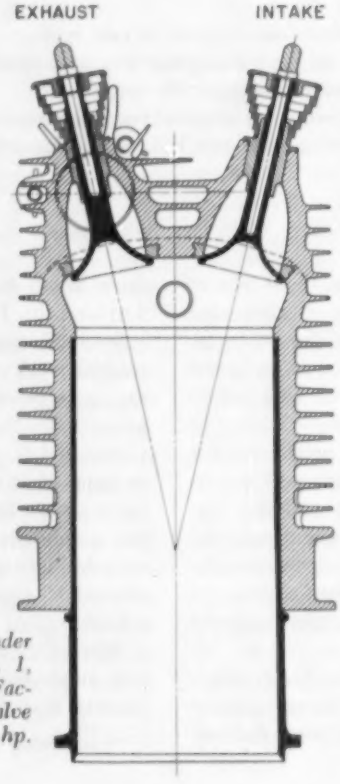


Fig. 2 – R.A.F. 4 D Aluminum Cylinder of Same Bore and Stroke as Fig. 1, Produced by the Royal Aircraft Factory in 1916. It is of overhead valve design and developed about 15 hp.

For Boot's first cylinder an aluminum casting was made from the pattern for the cast iron cylinder of 105-mm. bore. This embodied a cast-in exhaust seat insert of mild steel and was machined to take a carbon steel liner of 100-mm.

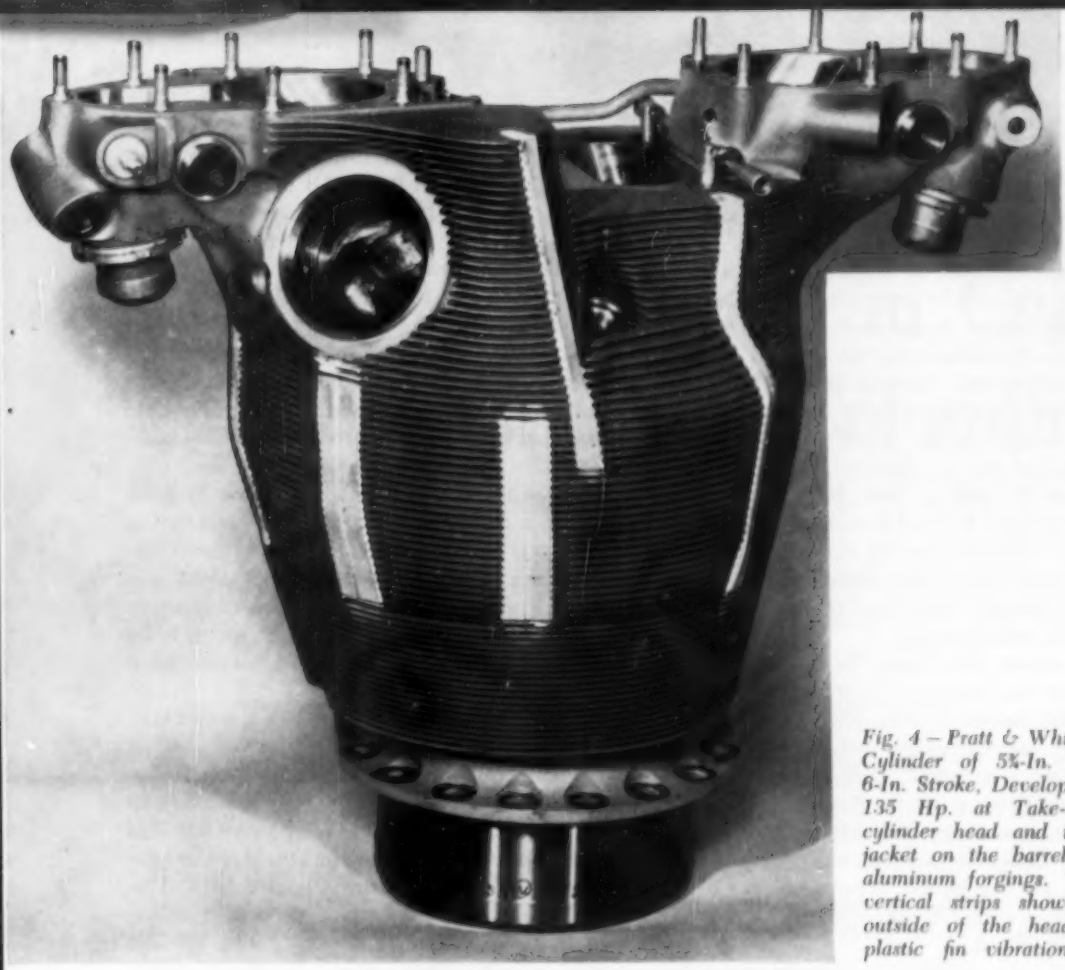


Fig. 4 – Pratt & Whitney 4360 Cylinder of 5¾-In. Bore and 6-In. Stroke, Developing About 135 Hp. at Take-Off. The cylinder head and the finned jacket on the barrel are both aluminum forgings. The white vertical strips shown on the outside of the head fins are plastic fin vibration dampers

bore and about 1.5 mm. thick. This cylinder tested so successfully that a design based upon aluminum and a 100-mm. bore was prepared similar to Fig. 2 and 3. This design was laid out and detailed by the writer under the direction of Wilkinson and Green. (Boot had left the Royal Aircraft Factory shortly after the conclusion of the tests on the first cylinder and was succeeded as chief engine designer by Wilkinson.)

The writer does not remember too much of the development history of the second cylinder except that it was initially made of an aluminum-zinc alloy and fractured on test in a relatively few hours. This was followed by more cylinders with an ever-increasing zinc content and a life inversely proportional to the zinc content. Finally a cylinder made of about 25% zinc alloy fractured after about 50 min. on test and hit a girder in the ceiling.

At this point Wilkinson decided to disregard the metallurgical advice from outsiders and had a cylinder cast in a piston alloy consisting of 7% copper, 1% tin, balance essentially aluminum. He had learned of this composition from analyzing a Belgian motor car piston in successful use before the outbreak of the War in 1914. This alloy was later known in England as 2 L 11 and was for a time extensively used for pistons.

The cylinder made of 2 L 11 alloy tested successfully and new designs of F-head cylinder with different fin arrangements were made and tested. These were a considerable improvement over similar cast iron cylinders in respect both to cooling and to specific fuel consumption. However, it was not until the first cylinder with overhead valves and hemispherical head (included angle between valves about 50°) was tested that the real potentialities of the aluminum air-cooled cylinder became apparent. The mean effective pressure, cooling and specific fuel consumption obtained during the first hour of running startled the engineering and research groups at the Royal Aircraft Factory.

In discussing construction of the first cylinder Boot told the writer he obtained the idea from an Italian designer. Boot did not mention the

man's name, whether the engine was air-cooled or water-cooled, the name of the engine, or where and when he had heard of it. The writer is under the impression that the engine must have been air-cooled; otherwise it would hardly have impressed Boot as original since he then knew of the Chevrolet water-cooled engines.

It is not known to the writer whether Boot realized the importance of the thermal conductivity of aluminum when he started his work. He may have been principally attracted by the potential weight saving, but it is probable that he recognized the conductivity factor since its importance in pistons was beginning to be realized. (Copper fins had been used on cast iron air-cooled cylinders prior to 1914.) In 1915 cast iron and steel were the standard materials for air-cooled aircraft engine cylinders, steel being used in the rotary engines.

It now sounds very simple to try aluminum as a substitute for cast iron but it was a considerable mental hurdle in 1915 when air-cooled engines were not uncommon with cylinders which could be seen at night! Cylinder temperature control was often uncertain; also the hot strength of aluminum was regarded with great suspicion by engine designers and had been compared to that of "a wet dog biscuit" — probably as a result of experience with aluminum-zinc or aluminum-zinc-copper alloys.

While the air-cooled engine was known to be unpleasantly hot in 1915 because its sins were naked to the world and could be seen and measured, the water-cooled engine largely escaped blame because its sins were cloaked. To Gibson goes the credit for the first systematic exploration of cylinder-wall temperatures in air-cooled engines. When he applied the same technique to water-cooled engines the results were by no means calculated to bolster the complacency of the designers!

The writer has been unable to trace Boot's movements subsequent to 1918 despite recent inquiries in England, and in consequence has been unable to check this note with him. He has therefore called upon friends to conduct a few historical investigations. Carlo Bona of Fiat (Italy) has made an extensive investigation and has been in touch with G. C. Cappa, C. Momo, A. Massimino, S. M. Viale and Florentino Lamberti. These gentlemen were all active in the field of aircraft engine design between 1913 and 1917. Without being in touch with Boot, it is of course impossible to identify the Italian designer who gave him the idea of aluminum as a cylinder material. However, it would appear probable that it was S. M. Viale. Viale built in France in 1911 an air-cooled engine with aluminum cylinder heads. The head was hemispherical and had valves seating directly in the aluminum. A cast iron barrel was used and the head was held onto the barrel by long bolts extending to the crankcase. Viale comments that he "experienced difficulty due to not having had the sense to think of valve seat inserts". Viale also mentions that at this period he tried aluminum pistons "with disappointing results". Whether Boot's work was a direct product of that of Viale must remain in the realm of doubt. Viale, however, seems to be the earliest pioneer of aluminum as an air-cooled cylinder material.*

The Bona search has resulted in a rather considerable file of information (in Italian). Among other items of interest, it has turned up Italian industrial patent No. 123058, "Improvements in the Construction of Light-Weight Aviation Engines" to Antonio Chiribiri of Turin, applied for Jan. 29, 1912 and granted Aug. 28, 1912. This patent claims steel liners and valve seat inserts cast into aluminum cylinders. Both Messrs. Cappa and Massimino remember the Chiribiri engine in about 1912.

The writer wishes to express his appreciation of the considerable trouble and effort that Dr. Bona has taken in conducting the research. Thanks are also due to the gentlemen who so kindly assisted Dr. Bona. To S. M. Viale (now of Coventry, England) the writer is indebted for detailed descriptions of Viale's early work. He is also indebted to the Ethyl Corp. for redrawing Fig. 1 and 2, and to the Pratt & Whitney Aircraft Div. of United Aircraft Corp. for permission to use Fig. 4.

In a day when emphasis is mostly on supersonic jet-propelled aircraft, discussion of what was probably the most important step in air-cooled aircraft engine cylinder development may seem pointless. To the writer it does not seem pointless to offer belated acknowledgment to Boot and to an Italian who inspired Boot. These pioneers made a considerable contribution to aircraft development. Their work has not hitherto been acknowledged mainly because few knew of it and no one took the trouble to record it in the archives of aircraft engine development.

*In the early 1920's, E. H. Dix, then of the Engineering Div., U.S. Army Air Corps (now assistant director of research for Aluminum Co. of America), evolved the foundry technique which resulted in the first satisfactory aluminum air-cooled cylinder castings produced in the United States.

A Turbine-Blade Alloy Castable and Low in Cobalt and Columbium

*By W. SIEGFRIED and F. EISERMANN**

An outline of systematic work to discover a "superalloy" capable of investment casting (mass production) and economical in scarce alloying metals. Work also was done which indicates that cast turbine blades are no more susceptible to thermal shock than the forged blades successfully used in gas turbines.

ALLOYS for ultra-high-temperature service are of first concern to builders of gas turbines, both for aircraft propulsion and for stationary or mobile power plants. Three major problems must be faced: First is adequate service under severe conditions of stress, temperature, and thermal shock. Second is formulation of alloys with minimum content of scarce and expensive metals. Third is a method of economical manufacture.

Taking up this last consideration first, it may be remarked that the blades used for turbines are of very complicated shape and require a great deal of machining if they have to be made from square bars. No less than 80% of the metal constituting the square bar has to be removed in order to produce the finished blade. In addition, metals of high hot strength are usually difficult to machine. In fact, alloys with the very best heat resisting properties cannot be put into the desired shape by machining processes.

Consequently, other methods of manufacture have been developed for turbine blades, namely forging and investment or "precision" casting. Forging is usually uneconomical except in mass production. In the Swiss mechanical engineering industry, the numbers of components of the same shape are strictly limited, so that investment casting seemed to offer the best prospects of success. It has the further advantage of enabling small turbine rotors to be made in one piece, complete with blades.

Precision cast gas turbine parts raise a number of new problems in the metallurgical field. Exhaust-gas turbines in motor cars, for instance, will eventually call for such large numbers of components that the high-temperature alloys must have smaller percentages of such important elements as cobalt and columbium than the common forged alloys in use today. Sulzer Brothers have for this reason undertaken rather extensive researches to develop new "lean" alloys of this type. These investigations have progressed in three stages, as follows:

Stage No. 1 – A matrix containing 25% Ni, 18% Cr, 0.2% N, balance Fe, was first selected, and various percentages of C, W, V, Mo and Cb were added to it. This was done by keeping the carbon content at a constant level of 0.1, 0.2 or 0.3% and then varying the percentages of W, V, Mo and Cb in such a way that their sum was always either 4% or 6%. Creep tests at 700° C. (1290° F.) and at loads of 33,000 and 22,700 psi. were then conducted on the alloys thus obtained. Since the sum of the four variable elements is always kept

*Engineering Dept., Sulzer Bros., Ltd., Winterthur, Switzerland.

constant, each chemical analysis can be plotted on a definite point in a tetrahedron, with the contents of W, V, Mo and Cb plotted along the edges.

Since a certain scatter was observed in the creep tests, the results were evaluated by rating them on the basis of logarithmically graduated time intervals as follows (for a load of 33,000 psi. and a temperature of 700° C.):

Quality Figure	Time Interval to Rupture
1	0 to 10 hr.
2	10 to 25
3	25 to 62.5
4	62.5 to 156.5
5	156.5 to 391.5

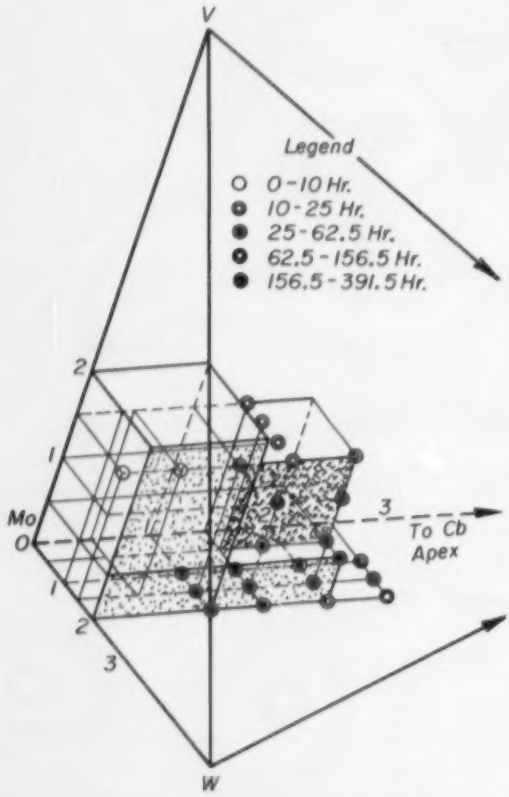


Fig. 1 — Results of Creep Tests on Alloys With 25-18-57 Ni-Cr-Fe Base All Containing 0.2% N, 0.1% C and W + V + Mo + Cb = 6%. Stress is 33,000 psi., temperature is 700° C. (1290° F.). Alloys of highest hot strength have little or no vanadium

Figure 1 shows the results of creep-to-rupture tests on this first family of alloys, based on 25-18 Ni-Cr, with a total of W, V, Mo and Cb equal to 6% and a carbon content of 0.1%. Each time interval is given a characteristic marking, and it can be seen that the alloys with highest hot strength are on the basal face of this tetrahedron — that is, contain no vanadium.

Stage No. 2 — When the zone with the best matrix alloy composition had been found, a series of alloys were formulated and tested wherein the matrix itself was varied, an increasing percentage of the nickel being replaced by manganese and cobalt. It proved that the optimum strength at high temperatures was at a ratio of Mn to Co of 1:1, and in the alloy which had the longest life at 33,000 psi., 8% of the nickel was replaced by 4% manganese and 4% cobalt. Figure 2 shows time to fracture for an alloy with 3% Mo, 1.5% W and 1.5% Cb loaded at 33,000 psi. as a function of the amount of nickel replaced by corresponding amounts of manganese and cobalt, and clearly reveals that the optimum results are obtained when 8% Ni is replaced by 4% each of Mn and Co.

Stage No. 3 — A third series of tests was then carried out with this optimum matrix containing Fe, Cr, Ni, Mn and Co. As in the case of the original Cr-Ni-Fe matrix, studied in Stage No. 1, the percentage of the alloying elements W, V, Mo and Cb was once again varied so that their sum was always 6%. The times to fracture obtained in the subsequnt creep tests at 700° C. are again plotted in Fig. 3. If we compare Fig. 1 with Fig. 3, we see that the times to rupture have all

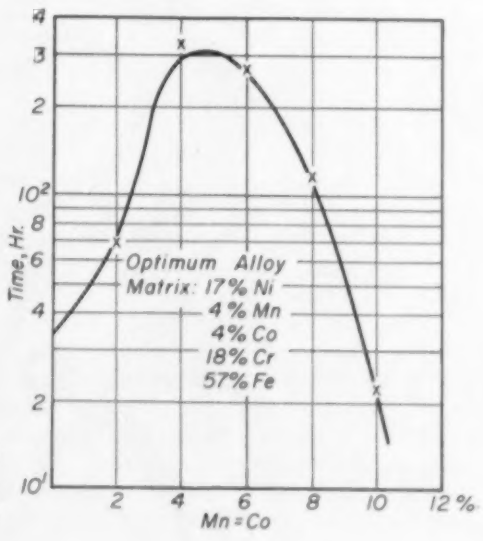


Fig. 2 — Time for Rupture at 33,000 psi. and 1290° F. of Optimum Alloy of Fig. 1 as the Nickel Is Replaced by Equal Parts of Manganese and Cobalt

been improved by 1 to 2 grades of our quality rating. We also see from Fig. 3 that the best results are obtained with 1% Cb, 2% W, and 3% Mo.

On the basis of these investigations, the composition of our new experimental alloy was fixed as follows: 0.1% C, 0.2% N, 18% Cr, 17% Ni, 4% Mn, 4% Co, 1% Cb, 2% W, 3% Mo, balance Fe.

Eight different melts were made to this basic analysis wherein the percentages of the alloying elements were varied within the limits which would normally be expected in foundry production of investment castings – namely, 0.1% C+0.2, 0.2% N−0.1, 18% Cr+0.8, 17% Ni−0.8, 4% Mn+0.7, 4% Co−1.0, 1% Cb+0:.6, 2% W+1.0, 3% Mo+0.9, 0.80 to 1.40% Si.

Furthermore, the cast test bars were heat treated in various ways, to take account of the fact that cooling conditions of production castings (in the mold) may vary to a considerable extent. Some bars were tested as cast; others were reheated to 750° C. (1382° F.) for 24 hr. and furnace cooled or air cooled; others were oil quenched after 5 min. at 1200° C. (2200° F.) and then heated 50 to 100 hr. at 750° C.

A considerable number of stress-rupture tests were made at 650, 700 and 750° C. (1200, 1290 and 1380° F. respectively) and as shown in Fig. 4, the scatter to be expected from this alloy in service because of the above manufacturing variables is slight.

The strength properties of two English high-temperature alloys, widely used, have also been entered in Fig. 4 in color. Comparison with G 18 B (0.40% C, 10% Co, 13% Ni, 14% Cr, 2% Mo, 3% W, and 3% Cb) shows that more than half of its cobalt and columbium can be saved by adding manganese, without the hot-strength properties being reduced at 750° C.

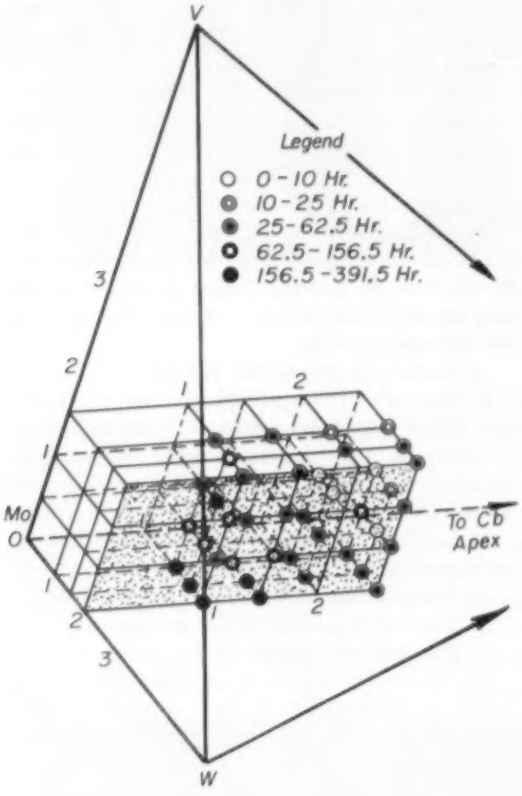
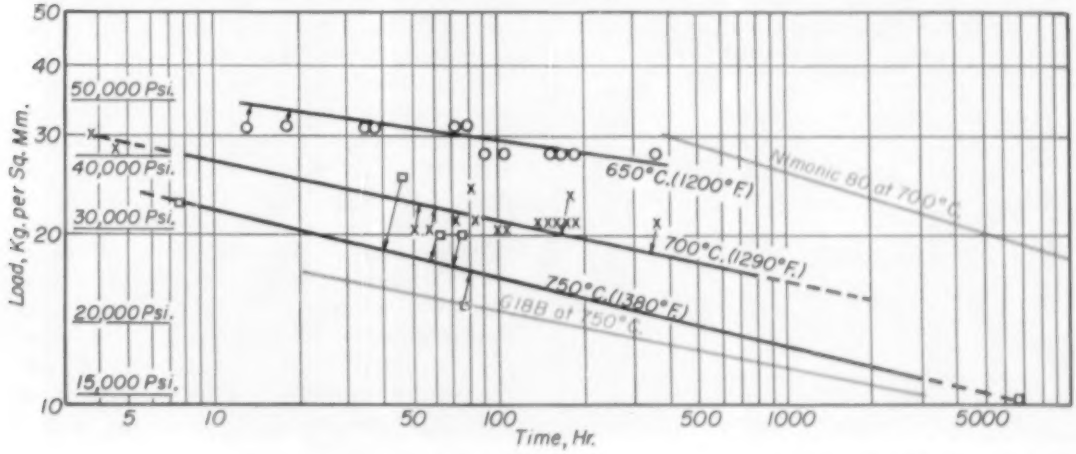


Fig. 3 – Creep Results on Alloys of Fig. 1 When 8% of the Ni in the Matrix Is Replaced by 4% Mn and 4% Co

Fig. 4 – Rupture Strength at 650, 700 and 750° C. on Several Heats of New High-Strength Alloy, Low in Nickel, Cobalt and Columbium. Creep tests were made on bars cast by investment molding process and heat treated in various ways



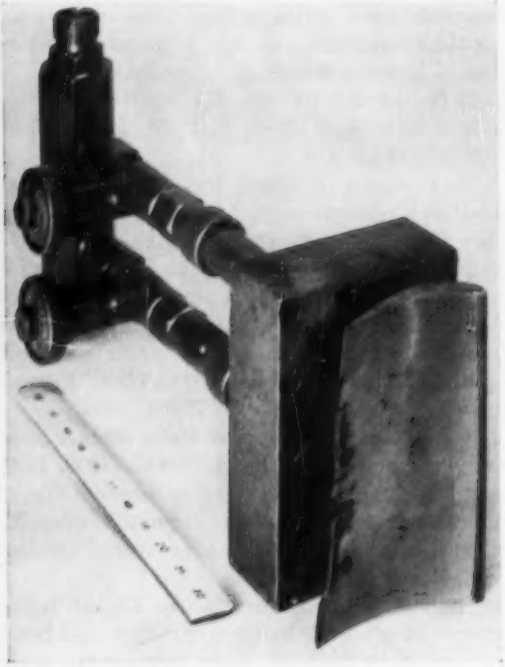


Fig. 5 – Design of Burner Used for Thermal Shock, and Relation to Blade Under Test. Ruler is in cm.

Thermal Shock – In aircraft turbines it is the stationary blades which are particularly exposed to rapid changes of temperature. When the engine is started the blades are brought up to the service temperature in a fraction of a minute, and they are cooled equally quickly when the fuel supply is cut off. This treatment frequently cracks the blades, and it was therefore necessary to determine whether cast blades have the same resistance to thermal shock as the forged ones.

Table I – Blades of Conventional Analysis Tested Under Thermal Shock

Element	Forged* S 816	Forged Nimonic 80	Cast Stellite 31 (X 40)
C	0.40	0.05	0.50
Ni	20	75	10
Cr	20	20	25
Co	43	1.5	55
Mo	4	—	—
W	4	—	7
Cb	4	—	—
Ti	—	2.5	—
Al		1.0	

*Prior to testing these blades were heated to 1230° C. (2250° F.) for 15 min. and quenched in oil.

A number of physical processes take place during this rapid and nonuniform heating:

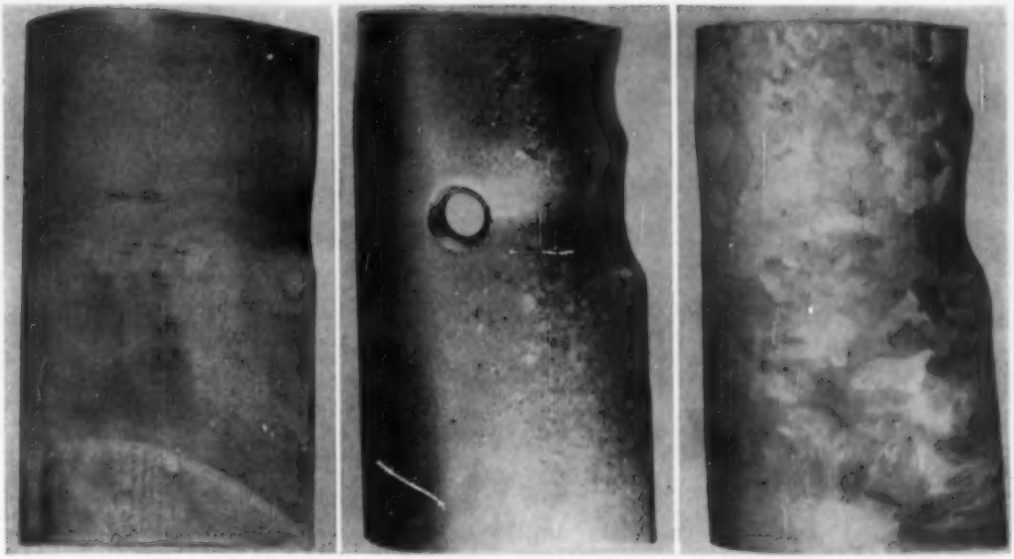
First, owing to a finite value for the thermal conductivity, rapid cooling leads to a cold surface and a hot interior. Hot metal occupies more volume than cold. Nonuniform temperature distribution and thermal expansion produce internal stresses which may exceed the yield point, locally. Alternate rapid heating and cooling then cause the yield point to be exceeded in some places, the stresses alternating in the tensile and compressive directions. This type of fatigue stressing leads to destruction.

In the second place, oxidation or other chemical reactions with the hot gases may take place on the surface and cause cracks to form, and this may combine with the alternating stresses already mentioned to cause failure. The interplay of the various influences is very complex and the single factors have so far defied quantitative determination. In general, it may be said that the magnitude of the internal stresses depends on the following factors:

1. Shape and size of the component.
2. Nature of the approach flow of the gases and of the heat transmission. (A most important question is whether the heating is local or whether the whole component is exposed uniformly to the gas flow.)
3. Intensity of heating and cooling (coefficient of heat transfer).
4. Temperature to which it is heated.
5. Thermal expansion of the component.
6. Thermal conductivity of the metal.

The tendency of a given metal to form cracks under conditions such as these depends in turn principally on the strength properties of the metal at high temperatures and the sensitivity of the surface to reactions with the gas phase.

Since the physical processes involved are not completely understood, the testing under thermal shock has to be carried out on an empirical basis. Two principles must be observed in such tests; they are to some extent self-contradictory: First, the stress should be of the same character as that occurring in the actual component; as far as possible, the shape, approach flow, intensity of heating, and other conditions should be essentially the same as in actual service. Secondly, since the machines must not fail during service and the service period is often much too long to be reproduced in the tests, the stresses applied must be more severe than they would be in reality, yet the relationship of the various factors must be maintained.



S816 Nimonic 80 H.S.31 or X40

Fig. 6 – Outside Surfaces of Three Typical Blades After 70 Rapid Heating and Water Quenching Cycles

The processes of destruction can be accelerated by the following expedients which serve primarily to increase the stress:

1. More drastic quenching (water quench instead of air cooling).

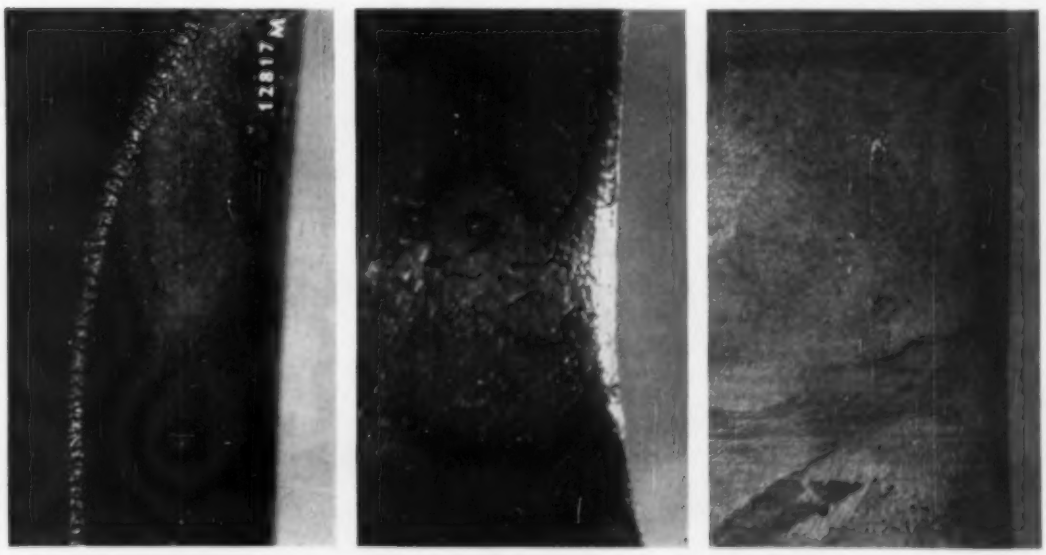
2. Nonuniform heating of the metal – for instance, by using a small burner and heating the component locally, or by directing the flow of hot gas onto the component from an unfavorable direction.

3. Increasing the temperature. This not only raises the stress but also lowers the life in comparsion to that expected in service, while the effects of oxidation and any other chemical surface reactions act in the same direction.

Our test rig consisted of a closed cylindrical

Fig. 7 – Cracks in Trailing Edges of Blades Shown in Fig. 6, Magnified 7 Diameters

S816 (Inside) *Nimonic 80 (Inside)* *H.S.31 (Outside)*



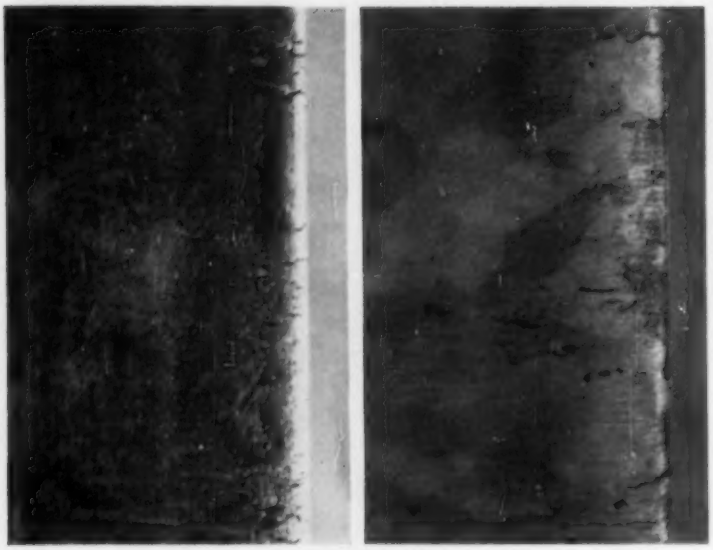


Fig. 8 – Cracks Along Trailing Edge, Inside of Forged Nimonic 80 Blade at Left; Isolated Cracks Along Trailing Edge on Outside of Cast Haynes Stellite 31 Blade at Right, Both After 500 Rapid Heatings to 900° C. Followed by Quenching in Cold Air Blast. 7×

tank, near the bottom of which was a round table, pivoted at its center, with fixtures to carry a full-sized blade at the quarter points around the circumference. On one diameter are two burners (Fig. 5); at the other diameter at 90° are two air jets for quenching. If desired, thermocouples can be attached to the blades (or in holes drilled to give internal temperatures) and the leads carried out a water-cooled central column to slip rings and thence to recorders.

The rotary table was driven through a Maltese cross and thus moved in jerks; in this way the blades are brought alternately before the burner and before a jet of quenching air or water. Before the actual tests were carried out, a study was made of the most favorable operations to make the conditions more severe. The influence of blade position and of alteration of the approach angles was also systematically investigated in advance.

It was found that the best results were obtained when a surface burner (Fig. 5) was used for heating and either a jet of cold water or cold air was used for quenching, the test temperature being raised 200° C. above the service temperature.

A few examples of thermal shock tests are cited below. Table I shows the chemical compositions of three well-known alloys which were tested in the form of blades, care being taken to see that exactly the same form was used for the cast and forged blades.

In the first series of tests the conditions were as follows: Maximum temperature, 900° C. (1650° F.); quenching medium, water; heating time, 90 sec.; cooling time, 10 sec.; number of reversals, 70.

Figure 6 shows three typical blades after the tests, while Fig. 7 illustrates the type of damage caused. Aside from the fact that the thin, trailing edges of the blades are bent to one side, cracks are observed. In the forged and annealed S 816 blade, numerous shallow cracks occurred on the trailing edge. In the forged Nimonic 80, several short cracks opened on the trailing edge. In the cast Haynes Stellite 31 blade, some cracks about 3 mm. long entered from the trailing edge, together with a few small cracks which appeared on the surface itself.

In a further series of tests, air quenching was employed. The test conditions were the same as before except the cold air blast was on the blade for the full 90-sec. cycle. Also the test ran to 500 reversals.

Figure 8 shows the cracks which formed in two of the blades. (Forged and annealed S 816 did not crack under this treatment.) In the Nimonic 80 blade there were many small cracks on the trailing edge. The cast H.S. 31 blade also cracked, although the cracks were few in comparison with the Nimonic 80.

Conclusion – It is apparent from these tests that the belief that cast blades are generally less resistant to thermal shock than forged blades is erroneous. It is shown that they can possess as good strength properties as the forged alloys which have given quite a successful record in service.

Improvement of Case Hardened Parts by Controlling Internal Stresses

*By JACQUES POMEY**

Proper compressive stresses at and near the surface which raise the endurance limit by 40% can be put into a machine part by carbo-nitriding followed by heat treatments which produce either a bainitic core, a pearlitic core, or a slightly spheroidized core, yet retain a surface approaching 1000 Vickers hard.

MANUFACTURE of machine parts with pre-stressed surfaces is not new. Witness the general use of shot-peening for improving the endurance of rotating parts. Likewise it has long been known that case hardening can set up surface stresses in a part which are favorable to its service, over and beyond the advantages of wear resistance.

However, we believe that we in the Central Research Laboratories of the Renault Co. were perhaps the first to make a systematic study of the pre-stressing of a machine part by modern heat treatments such as carbo-nitriding and isothermal transformation, leading to the setting up of exact heat treatment schedules for automobile parts. A remarkable increase in quality has been achieved at small cost and without adding to the alloy content of the steels.

This article will outline the theoretical basis of our improved practices, compare some examples of the properties of test pieces treated in the conventional and the improved manner, and give some of the heat treating schedules now in wide use throughout the Renault factories.

Origin of the Research – The high fatigue resistance of a rotating beam test piece, case hardened, cannot be explained by the properties of the microstructure in case and core. Moreover, if a cylinder is hardened on its inside surface and then slit longitudinally, it will spring open; the hardened surface must have been under compressive stress.

While case hardening has been long used for protecting the part against impact, erosion, abrasion, or frictional wear, it occurred to us that we might take advantage of the residual compressive stresses at and near the surface to counteract in part the stresses met in service – especially those of simple and alternating tension, torsion in round members, and the concentration of stresses at notches or corners. Thus, it should be possible to postpone or prevent failure by deformation, brittle fracture, fatigue or corrosion fatigue, since all of these start in weak surface regions.

A Little Theory – Theoretically, the internal forces in a metallic body are heterogeneous and are unbalanced at the extreme surface, and this is therefore accompanied by the greatest strain and unbalance in the atomic arrangement. Hence the surface is intrinsically hard. To avoid a tendency toward cracking, the surface must contain suitable compressive stresses. Compressive stresses must also be developed at the surface to counteract in part the tension stresses induced by service loads.

When this is done, internal equilibrium requires that balancing forces must exist in the

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metal part below the hardened surface which contains the residual compressive stress. A case hardened round bar, therefore, carries triaxial tension stresses in the core. Since triaxial stress – as is well known – leads to brittle or cleavage type of fracture, this dangerous state of affairs is avoided in practice by providing a core of metal which is intrinsically elastic and malleable, and also properly proportioning the hardened case depth to the cross section of the part.

Manufacturing considerations also favor a comparatively shallow case. A surface-hardened shaft, for example, must safely endure straightening after heat treatment. Massive parts must be free of internal quench cracks.

Briefly the theory is this: Since the service stresses in a machine part vary from point to point and are usually greatest at the surface, the fabrication methods and especially the heat treatments must themselves be heterogeneous so as to develop in every location the most favorable microstructure and state of stress, especially at the surface. Ideally, the result would be a solid of equal resistance to the working loads in all its elements, and if the loads were increased, the limit of strength would be reached everywhere in the part simultaneously.*

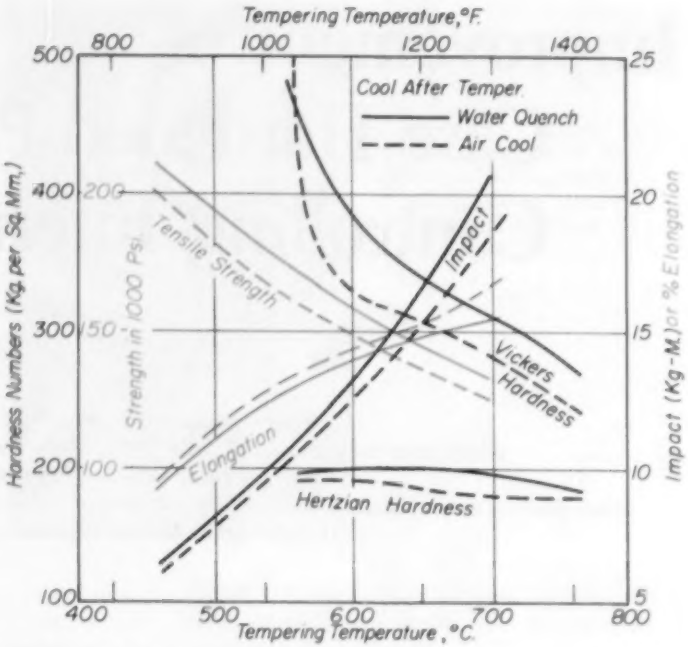


Fig. 1 – Influence of Pre-Stress at Surface on Properties of Test Pieces, Austenitized at 1000° C. (1830° F.) and Air Cooled, Then Reheated to Indicated Temperature, Followed by a Water Quench or Slow Cool. Steel contained 0.40% C and 13% Cr. Mesnager impact test pieces (10 mm. square, round bottom, notch 2 mm. wide and deep). Tensile strength is for notched test pieces; elongation is for unnotched test pieces

Properties of Pre-Stressed Parts

General properties resulting from a state of pre-stress may be determined by comparing test pieces with the same microstructure – for example, pieces quenched and tempered alike, but one set air cooled from the tempering temperature and the other water quenched. As shown in Fig. 1, at tempering temperatures varying from 460 to 760° C. (860 to 1400° F.) the pre-stress induced by water quenching after tempering will increase the hardness and impact energy, but will decrease the elongation in the tensile test – a paradoxical result but one which conforms to the supposition that rapid quenching induces triaxial stresses in the body of the part.

A further and very important effect is the increased strength of a notched tensile test. It is well known that a notch has two effects – (*a*) concentration of tension stress at the root which has great influence on the tensile load which the entire part can sustain, and (*b*) the creation of triaxial stresses, almost hydrostatic or equal in all three dimensions so plastic flow is impossible at the root or bottom of the notch, and this is where failure starts.

Endurance limit may be measurably affected by pre-stress of the extreme fibers of a rotating test piece in two different ways. In the hardened case, we should by all means avoid weak points or even microcracks which may be the nucleus

*Editor's Footnote – Americans will recall Oliver Wendell Holmes's rhyme about "The Deacon's Masterpiece":

Have you heard of the wonderful one-hoss shay
That was built in such a logical way
It ran a hundred years to a day?
. . . . . .
It went to pieces all at once –
All at once, and nothing first
Just as bubbles do, when they burst.

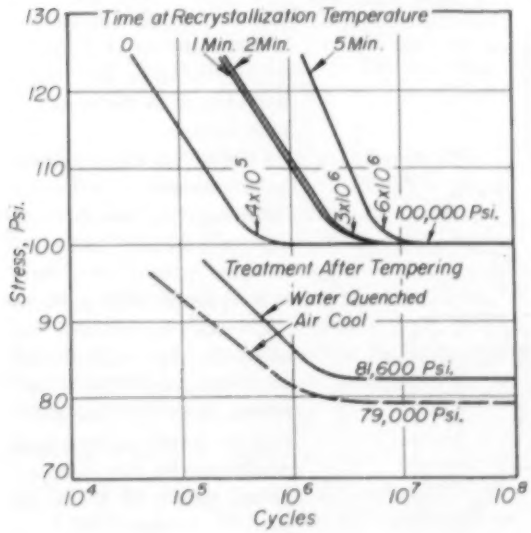
of fatigue failure. On the other hand, we may improve either the case or the core by refining the crystalline grain and so distribute the stresses more uniformly throughout the structure.

Pre-stressing a given structure by heat treatment will improve the endurance limit somewhat, and this is shown in the lower pair of curves in Fig. 2 for the 13% chromium steel described in the caption of Fig. 1. When this steel is austenitized at 1000° C. (1830° F.), air cooled, reheated at 660° C. (1220° F.) for 20 min. and then water quenched, its endurance limit is 81,600 psi., whereas if air cooled its endurance limit is 79,000 psi. The microstructure of the two samples is identical; the compressive stresses induced by quenching after tempering are measured in terms of the improved endurance limit.

The effect of grain refinement is demonstrated by the curves in the upper part of Fig. 2. These represent rotating-beam endurance tests on a steel whose composition is 0.10% C, 2.25% Ni, 1.0% Cr and 0.65% Mn, gas carburized at 900° C. (1650° F.) to a depth of 0.8 mm. (0.03 in.). This steel was then slightly cold drawn and recrystallized to different grain size by reheating 1, 2 or 5 min. It will be seen that grain size within these limits does not influence the fatigue limit (100,000 psi.), but it does strongly affect the number of alterations of higher loads which are resisted before failure.*

In the present state of our knowledge, we cannot calculate the effect of pre-stress on endurance. Yet it is undoubtedly more favorable than we had expected. This is because the stresses in a test piece are distributed in a different manner than in a working part. Furthermore, the intrinsic properties of the metallic structure appear to be modified favorably by the first few cycles of even moderate alternating stress. The combined result is that the stresses induced metallurgically distribute themselves more harmoniously with respect to the service-induced loads, thus tending toward the production of a more reliable part in service.

Fig. 2 — Influence on Endurance Limit of Pre-Stressing Surface by Heat Treatment (Lower Pair of Graphs) and of Coarsening the Grain Size (Upper Curves)



Measurement of Stresses at the Surface

Because of the high hardness and the thinness of the hardened case, one cannot estimate its locked-up stresses by the ordinary method of measuring the diameter of a round bar after broaching successively larger holes through its axis. X-ray diffraction methods do not give sharp enough lines to estimate the distortion of the crystalline lattice. So we had to find a new method.

We discovered that the hardness of a quenched steel, measured by the Vickers machine, would be lowered merely by scratching the surface and thus relieving the superficial compression stresses slightly. This led us to suppose that the Hertzian hardness could reflect the variation in internal stress more pronouncedly, and this proved to be true.

The Hertzian theory of hardness may be exemplified by considering a ball which is pressed lightly into a surface. The original point of contact becomes a tiny circle, the mean normal pressure over the contact area at the beginning of plastic flow is a measure of hardness, and it is related to the elastic constants and elastic limits of the material under test.

In our equipment, sketched in Fig. 3, a 2.12-in. circular disk D of steel can be dished by screwing the cap C down over base B. The nose of the anvil A is spherical with the same radius as the 10-mm. ball S. Load is 400 g., and area of contact is estimated by resistance to an electrical current brought in through the connections indicated. In this equipment, Hertzian hardness can be related to surface stress in the disk as it is deflected.

Since the Hertzian method measures the hardness of the most superficial metal, we could compare the hardness (and hence the stress) at the surface of a heat treated piece with that of a

*We have also demonstrated that compression pre-stresses improve the corrosion-fatigue limit.

disk of the same metal with the same metallographic structure under known imposed stress, either tensile or compressive. Figure 4 gives the results of such a test on a piece of nickel-chromium steel with 1% carbon, hardened to Rockwell C-58 by quenching from 850° C. (1560° F.) into salt at 250° C. (480° F.) for 3 min., air cooled and then tempered at 250° C.

Note that this method is direct in the sense that pressure opposes the internal stress; all other methods are extensometric. The test is easy and rapid. Finally, it is applicable to all parts and is nondestructive.

Case Carburizing Plus Isothermal Quench

In order to make the most of the pre-stresses in a carburized part, we must first put the core into a stable microstructure and then harden the case by martensitic transformation. The increase in specific volume of the martensitic surface, held down firmly to its ductile core, causes favorable compression stresses to arise in the hardened case.

This succession of transformations – first in the core, then in the case – can be achieved by utilizing their different rates of incubation and transformation, or by working in the different critical temperature ranges of the reversible equilibrium, $\gamma \rightleftarrows \alpha$.

Let us first consider the practice of carburizing (or carbo-nitriding) followed by isothermal transformation of the core into bainite. Its elements may be explained by the TTT-curves or isothermal transformation curves for a carburizing steel with 0.18% C and another of the same analysis except it contains 1.03% C. One will represent the core of a carburized part and the other its case. In Fig. 5 the dotted line *a-a'* represents beginning of transformation at indicated temperatures for the 0.18% carbon core, and dotted line *b-b'* represents 90% transformation. Full lines *c-c'* and *d-d'* represent corresponding circumstances for the 1.03% carbon case.

Note the hatched area in the central portion which determines the time-temperature conditions wherein our desired results will be obtained; namely, the core is totally transformed to bainite (with room-temperature hardness of about 240 Vickers) while the case remains austenitic, being transformed to martensite 775 hard only when cooling through the M_s range.

In reality, the phenomenon is considerably more complex, and we must bear in mind the following factors:

The bainite in the core is the stronger and tougher the finer its grain size – that is, the lower the temperature of transformation. Proper temperature of the isothermal quenching bath would therefore be 260° C. (500° F.), near the lower edge of the hatched region, as shown by P, Fig. 5.

Complete transformation into bainite may be very slow; consequently, we content ourselves with almost complete transformation such as achieved in 1 min., just to the right of the 90% transformation line *b-b'*

Rate of cooling, after isothermal transformation of the case, should be such that a proper amount of austenite is retained in the martensitic case. Here again is a means of controlling deformation and improving service performance. The correct amount of residual austenite can be had by cooling (refrigerating) the piece to a proper subzero temperature.

The desirable properties of the martensitic case must not be altered by later manufacturing processes, especially cold straightening. Consequently, great care should be taken to avoid warpage or deformation by rough handling or as the result of poor fixtures.

Control of Deformation – Deformation due to the difference in specific volume of austenite and martensite – which, of course, is inseparable with hardening – can sometimes be avoided by differential cooling through the M_s-M_f range. It is not necessary that the transformation into martensite be simultaneous in all points of the steel part. It is enough that it

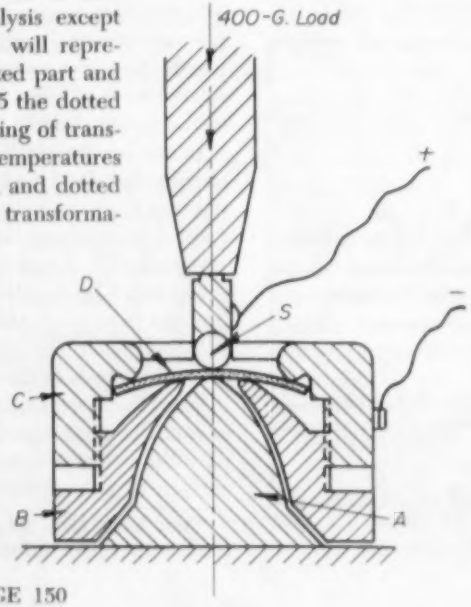


Fig. 3 – Apparatus for Measuring Hertzian Hardness of Hardened Disk D as Its Surface Stresses Are Changed by Elastic Deflection

occur slowly enough to permit a certain amount of internal yielding, and that tempering be prompt, so that the residual stresses always are considerably lower than the ultimate strength of the given microstructure.

In practice, warpage will not occur if all parts of the piece reach the temperature of the isothermal quenching bath *before* any transformation begins. For a piece of given mass this necessity determines the chemical analysis of the steel; in large pieces, costly alloying elements can only be avoided by increasing the carbon content. This is not always effective, for in case hardened pieces the carbon varies from high at the surface to low in the core through a transition zone wherein a mixture of bainite and martensite will occur if the incubation period is too short. (Figure 5 shows, by the position of lines *a-a'* and *c-c'* that this incubation period for the given Cr-Ni steel is between 10 and 20 sec.)

Alloy content and carbon content will limit

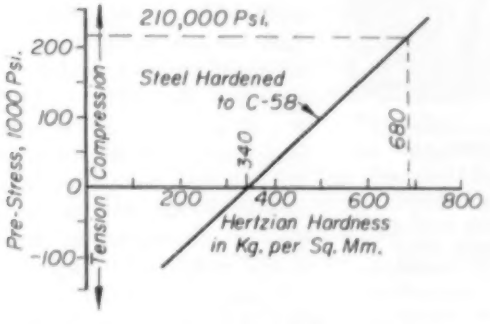


Fig. 4 – Variation of Stresses in Terms of Hertzian Hardness of a Nickel-Chromium Steel With 1% Carbon, Hardened to C-58. If there is no internal stress at the surface tested its Hertzian hardness is 340; if its Hertzian hardness is 680, the surface is stressed to 210,000 psi. in compression

the extent of the hatched area as shown in Fig. 5, whereupon a compromise is necessary in order to prevent the transformations in core and case from overlapping. Generally it is desirable to choose analyses which, when carburized, will have a lengthy incubation period. Frequently one can usefully supplement the delaying action of carbon by adding nitrogen – that is, by carbonitriding, without the necessity of enriching the analysis with alloying metals.

Residual Stresses at Depth

Most of the above quantitative work on internal stress has been confined to the very surface

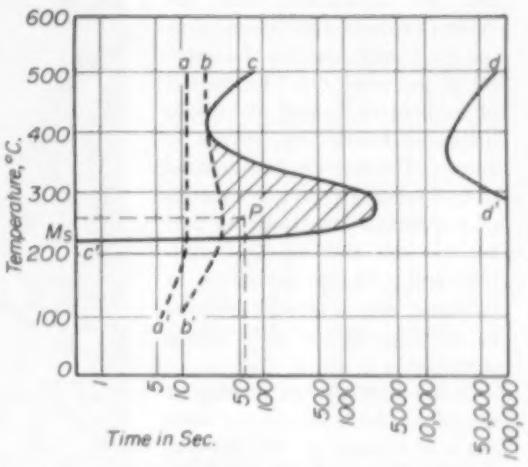


Fig. 5 – TTT-Curves for Two 1.35% Ni, 1.00% Cr Steels Representative of Case and Core of a Carburized Part. Curves c-c' and d-d' represent beginning and 90% transformation of a steel with 1.03% C; a-a' and b-b' are corresponding curves for 0.18% C

of a heat treated piece. We have also studied the stresses at various depths in a carburized layer of nickel-chromium steel, heat treated as indicated in the discussion of Fig. 5 and by the middle sketch of Fig. 8 – namely, rapid cooling in a salt bath to 250 or 260° C., isothermal transformation of the core only to bainite, martensitic transformation of the carburized case on cooling from 260° C. The main stresses produced by this succession of events correspond to the axes of cylindrical coordinates, so their summation is easy.

1. We treated an identical cylinder in the same way, but it was first silver plated so it could not be carburized. We determined the residual stresses in it by successively boring or broaching larger holes, longitudinally along its axis, and measuring its diameter. Stresses within such a piece are negligible – on the order of 7000 psi. in tension.

2. During the transformation to bainite, the core expands, and this stretches the case, which is still austenitic. The amount of this expansion was estimated by the lengthwise growth of the cylinder in a dilatometer. We estimated the stress necessary by stretching a comparative cylinder of austenitic steel the same amount. (It will be remembered that elongation of austenitic steel under tension test is general, rather than confined to a small portion or neck.)

3. Finally, the stresses produced in the case

can be calculated from the known expansion in volume during the transformation of austenite to martensite, if the amount of martensite formed at various distances below the surface is known. The latter was estimated in two ways: (*a*) by the kinetics of transformation based on carbon content and speed of cooling, and (*b*) by variations in hardness measurements, related to carbon content and microstructure.

In the steel and heat treatment described above, we found compressive stresses of 185,000 psi. at the surface rising gradually to 200,000 psi. at about one-third the case depth (0.45 mm. or 0.017 in.). At successively deeper layers the compressive stresses were sharply relieved, reaching zero at the full case depth of 1.2 mm. or 0.047 in.

Rotating-beam fatigue test pieces treated in this way had an endurance limit of 115,000 psi., whereas the same carburized steel oil quenched in the conventional way from the carburizing heat had an endurance limit of only 85,000 psi.

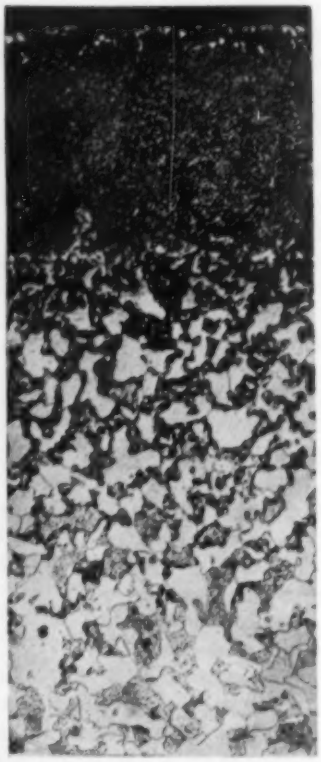


Fig. 7 – Microstructure of Surface Carbo-Nitrided at 700° C. 150 ×. Martensitic case, 0.15 mm. deep, is about 825 Vickers hard, and carries compression stress of about 140,000 psi. Pearlite in core is slightly spheroidized

Carbo-Nitrided Cases With Pearlitic Cores

With the aid of nitrogen (provided by the carbo-nitrided case), the temperature range of stability of the austenitic case is considerably lowered. The ternary Fe-C-N eutectoid transforms at 595° C. (1100° F.), considerably lower than the binary Fe-C eutectoid at 738° C. (1360° F.), and these figures are lowered somewhat by the alloying elements in constructional steels. There therefore exists a fairly wide range where the carbo-nitrided case is stable. 680° C. (1260° F.) is such a temperature which can be used in a treatment schedule such as the next-to-last diagram in Fig. 8.

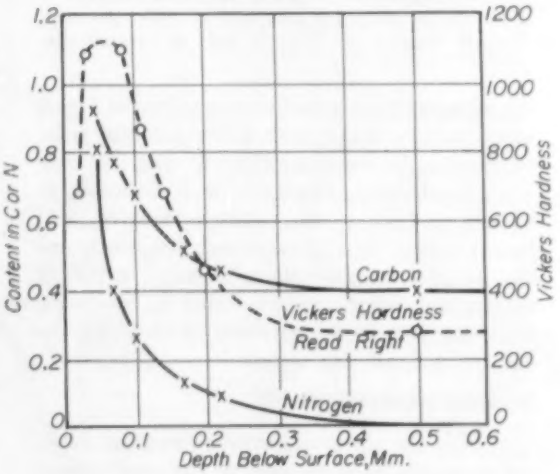
As a specific example, we treated a 0.35% C, 1.0% Cr, 0.3% Mo steel for 1 hr. 45 min. at 810° C. (1490° F.) in a gas containing 30% CO, 36% H_2 and 1% CH_3CN, long enough to form a case 0.2 mm. deep. The part is then rapidly cooled into the intermediate zone to 700° C. (1290° F.) and held 20 min., long enough for the core to transform into pearlite. Meanwhile the case remains austenitic. The part is then water quenched and refrigerated to −180° C. (−290° F.) to transform the surface layers thoroughly. During this cooling the pearlite core, of course, does not change.

Our stress studies indicate that the residual compression stresses in the surface layer after such a heat treatment reach 140,000 psi. although its depth is only 0.2 mm. (0.008 in.). Carbon and nitrogen anaylses and hardness traverse are shown in Fig. 6.

Carbo-Nitriding Below A_1 (1360° F.) – In this last process which we are using in the Renault works, carbo-nitriding is done between eutectoid temperatures of the Fe-C and Fe-C-N systems – say, at 700° C. (1290° F.), as shown in the right hand sketch in Fig. 8. In this process the core does not transform and only a very thin layer on the surface is austenitized by absorption of carbon and nitrogen.

For example, Fig. 7 shows the

Fig. 6 – Carbon and Nitrogen Analyses and Hardness of Carbo-Nitrided Case Treated to Put the Core Into Pearlitic Microstructure



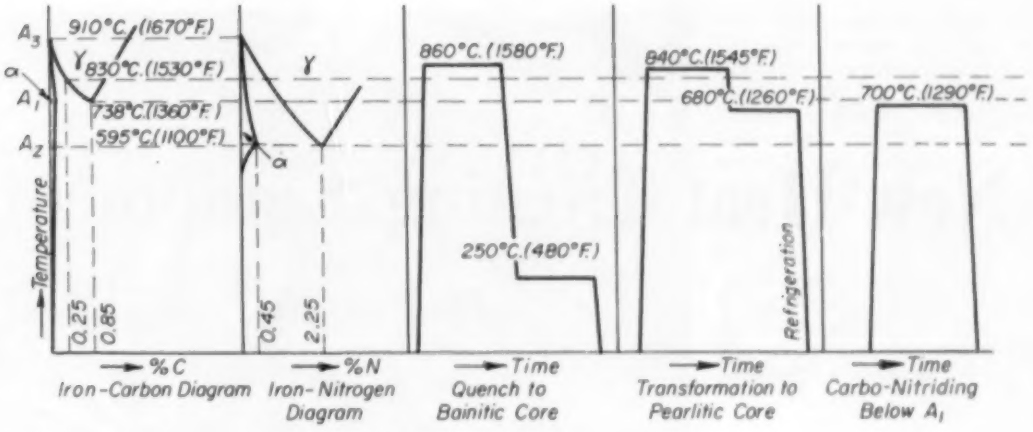


Fig. 8 – Three Heat Treatment Schedules for Carbo-Nitriding Automobile Parts to Insure High and Controlled Compressive Stresses in the Case

microstructure of the surface layers of a medium-carbon steel whose original microstructure consisted of small islands of pearlite surrounded by ferrite. In the core, after carbo-nitriding at 700°C (1290° F.), the cementite plates in the pearlite have been slightly spheroidized. At the surface, nitrogen first dissolves in the ferrite at 700° C. and diffuses inward. When the amount of dissolved nitrogen is high enough the small islands of pearlite transform into an Fe-C-N austenite. They grow by absorbing surrounding ferrite, and when the very surface has become completely austenitic, carbon begins to enter and diffuse inward.

On quenching, the austenite transforms to martensite. In the microsection shown, representing the outer 0.7 mm. (0.027 in.), the Vickers hardness at the surface was 880; 0.15 mm. below the surface the martensite was 825 hard; at 0.20 mm., where some pearlite particles appear in the transition zone, it was 750 Vickers. Hardness then dropped to that of the original core (about 200 Vickers) at a case depth of 0.50 mm. Compression stresses in the hardest layer were on the order of 140,000 psi.

Advantages – Nitrogen in the case hardening atmosphere permits the use of plain or alloy steels of all carbon contents. Cast iron, even, can be carbo-nitrided if the graphite is nodular or spherulitic rather than flaky.

The case depth can be controlled at will by regulation of time at temperature. The hardness and compression stresses appear only after the part is cooled.

Both because of the low temperature for carbo-nitriding, and the low transformation temperature of the nitrogenous austenite, the martensitic structure is always extremely fine-grained. Superficial hardness, as quenched and refrigerated, easily exceeds Vickers 1000. The surface structure tempers with reluctance, which explains in part its excellent resistance to wear.

Because of the moderate temperatures involved, the surface does not oxidize, except to the thinnest color film.

Since the core possesses a stable microstructure after quenching, deformation on tempering is very small, even after a heat treatment designed to give the optimum residual stress.

Conclusion

For all these reasons, the three carbo-nitriding cycles indicated in Fig. 8 are widely used in the manufacture of Renault motor cars and trucks. They give an ensemble of properties in low-alloy or plain carbon steels intermediate between those presented by (*a*) parts of higher chromium and nickel carburized at about 1650° F. in the conventional ways and rapidly quenched, and (*b*) parts made of chromium or aluminum steels nitrated a long time at low temperature and slowly cooled.

The Renault central laboratories have therefore been able to plan the detailed heat treatment of steel parts for definite service, thus expediting set-up and preparatory time. Remarkable results have been achieved with nitrogen atmospheres without having to resort to expensive alloying elements in the steels.

Heat treating so as to put optimum compressive stresses in the correct position has increased the life of automobile parts and prevented fatigue failures or wastage from wear.

New Heat Treating Equipment in Great Britain

*By TOM BISHOP**

Annealing of aluminum foil without crinkling, heat treating clad aluminum in salt baths without staining, continuous flash annealing are a few of the nonferrous developments cited; on the ferrous side, the author describes a "drip-feed" liquid for generating a carburizing atmosphere, and a scale-free heating method not yet in use in this country.

METALLURGICAL heat treatment is an applied science which is not prone to startling new developments in either method or plant. However, there is a steady, continual improvement in technique, based on a better understanding of basic principles brought about by research. Heat treatment is not concerned only with the ultimate heating and cooling cycle to produce required properties – the process begins at the initial operation prior to fabricating. A few examples of the latest methods and furnaces in use in Great Britain are discussed below; of course, the review is by no means exhaustive, but new and interesting examples have been selected.

Heat Treatment of Aluminum

Continuous Annealing of Foil – Stringent temperature control is required when heat treating aluminum alloys. At the temperatures concerned, heat is transferred in electrical systems mainly by convection, and recent developments have resulted in bigger and more powerful fans, and finally in the complete separation of the heating chamber from the work chamber, thus eliminating heat transfer by radiation, so that temperature uniformity is at a maximum.

In the annealing of aluminum foil, only by very even and uniform heating can the bugbear of "crinkling" be avoided. For this reason, the equipment shown in Fig. 1 is of unusual interest. A continuous furnace, it incorporates an external heater system applied up to recently on furnaces of the batch type. This installation replaced a battery of pit furnaces of the standard forced-air convection type. The requirements were an improvement in temperature uniformity and increased outputs with lower operating costs than could be obtained from a battery of batch furnaces of equal capacity.

As shown in Fig. 1, the heated air is blown via ducts provided at the furnace roof in each of the four zones through deflector plates. These are adjusted to insure uniform flow and back through the charge, using similar ducts at the side of the furnace below roller level. A system of dampers in the first two zones ventilates the vaporized lubricant from the work.

Four fans provide cool air to the cooling chamber; shutters in the sidewalls and roof of

*Editor, *Metal Treatment & Drop Forging*, London, England.

Fig. 1 – Continuous Chain Conveyer Furnace for Annealing of Aluminum Foil on Spools. The 30-ft. heating chamber is divided into four zones, each with its own external heater assembly – removable heater bank, centrifugal fan and temperature control. Built by the Electric Resistance Furnace Co. of Weybridge, England, with patented external heating system developed by their American associates, the Lindberg Engineering Co.

the ducting regulate the air as required. In this installation the air exhaust from the cooling chamber is utilized elsewhere in the factory.

To reduce labor costs, the system was made fully automatic. Operation of the inlet and outlet doors is synchronized with the double-track conveyer chains and sequence-controlled with adjustable time cycles to suit foil gages. The only manual effort that is required is to load the charge carriers onto the inlet rollers from a roller-topped table.

The furnace is rated at 350 kw. Output is 1 ton per hr. when operating on a 55-min. cycle handling foil gages of 0.022 to 0.025 mm., and is 0.7 ton per hr. when handling lighter gages down to 0.017 mm. on a 35-min. cycle. In contrast to previous practice, "crinkling" is claimed to be nonexistent.

Staining of Aluminum Alloy – Heat treatment of clad aluminum alloy sheet in molten sodium nitrate baths is common practice and, among other advantages – notably, short heat treatment time – it does not greatly impair the surface finish produced by cold rolling. When a bath becomes slightly alkaline, however, it may stain the sheets spasmodically, sometimes sufficiently to reject appreciable quantities of finished sheet. Information on this was recently given in a paper to the Institute of Metals (London) by E. C. Williams and H. J. G. Challis, of Imperial Chemical Industries. Staining of clad aluminum alloy sheets in baths of molten sodium nitrate at

Fig. 2 – Flash Annealing Furnace Developed by Stordy Engineering Co., Ltd., Will Handle Aluminum Sheets 6 Ft., 6 In. Wide and Circles Down to 5 In. Diameter at a Rate of About 2 Tons per Hr. A small model, designed to handle sheets up to 4 ft., is also in production

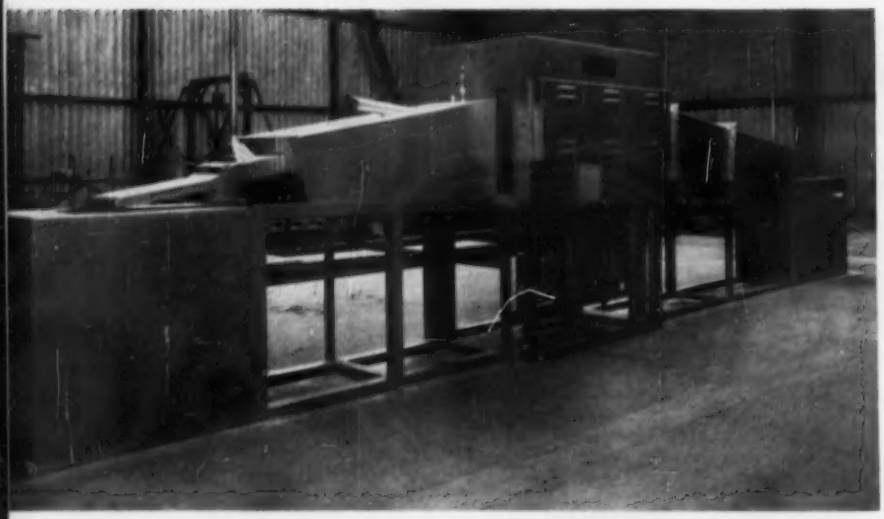


Fig. 3 – Hump-Back Furnace for Sintering or Annealing Powder Metal Compacts. Courtesy A. R. Wade, Ltd.

930° F. is primarily associated, they find, with abnormal amounts of free alkali in the salt. When salt containing more than 0.03% of free alkali (expressed as Na_2O) is chilled at the surface of a sheet entering the bath, alumina is formed and staining occurs almost instantaneously. At concentrations of free alkali above 0.10%, a stain consisting of sodium aluminate is formed on prolonged immersion. In production, staining is mostly of the instantaneous kind.

Control of free alkali is therefore essential. Conditions which tend to accelerate decomposition of salt and to increase free alkali must be avoided. The authors recommend that the amount of sodium nitrite added to the bath be restricted to the minimum compatible with a satisfactory life of the iron containers. Accidental contamination of baths with foreign matter, such as oil or grease, likely to accelerate decomposition, should be kept to a minimum. Furthermore, time at heat above 930° F. should be as short as possible.

Baths that are liable to stain may be reconditioned by treatment with gaseous carbon dioxide until the free-alkali content is brought below 0.03% Na_2O. Baths containing added nitrite can also be reconditioned in this way.

Rapid Annealing of Aluminum—Continuous "flash annealing" is a process for rapid treatment of aluminum and aluminum alloy sheet, to avoid pack annealing. The function of a furnace for this purpose (Fig. 2) is to heat the metal to its annealing temperature in 2 to 3 min., thus giving rapid, even and uniform recrystallization, and then immediately cool; thus the whole annealing process is complete in such a short time that grain growth is reduced to a minimum.

The units so far in operation are all arranged for electric heating, and are provided with an intensive system of air circulation. The annealing procedure is laid down for each thickness of sheet (or circle) as a function of furnace temperature and time, and the conveyer drive is fitted with an infinitely variable speed control.

Nonferrous Heat Treatment

Beryllium Copper – Beryllium-copper components for aircraft are now being heat treated in a new 60-kw. horizontal furnace with forced-air circulation. It operates at temperatures up to 1300° F. and is made by the (British) General Electric Co., Ltd. The cylindrical chamber is 11 ft. long and 2 ft. 6 in. in diameter. For uniform temperature, elements of nickel-chromium tape in sinuous form are arranged behind a heat resisting steel lining along the length of the furnace. The air flow is guided over the elements behind the inner lining and so heated before passing through the chamber. The air impeller which operates at the rear of the muffle is carried on a shaft with water-cooled bearings and driven by a 5-hp. motor. The charge is inserted on carrier trays which run on heat resisting steel tracks fitted in the chamber.

Powder Metals – The furnace for sintering and annealing shown in Fig. 3 is of the hump-back design; advantages are low atmosphere consumption and the absence of burn-off flames. This design is not limited in its application; it is in use in a variety of industries and several

furnaces have been supplied to a large radio valve manufacturer for degassing purposes.

Equipment and Processes for Steel

Drip-Feed Gaseous Cementation—Atmospheres in general use for gas carburizing all contain carbon monoxide, methane and hydrogen. Although they may be generated in several ways, the methods employed in Britain are broadly two: (*a*) City gas (in English it is "towns' gas") or piped methane is treated in a separate gas plant, and usually enriched with a hydrocarbon gas; (*b*) A suitable liquid mixture is dripped directly into the carburizing furnace chamber.

In the prepared towns' gas method, (P. T. G.), one technique is to purify raw gas by a catalyst with the result that the carburizing constituents naturally present in it are rendered extremely active. In the second method, atmospheres are derived from suitable organic liquids such as mixtures of alcohols or hydrocarbons which are pyrolyzed in the furnace chamber to produce an effective carburizing potential. Although this method appears to be simple, a number of points must be watched carefully to insure repetitive and controlled results.

For example, many mixtures tend toward undue amounts of sooting caused by over-richness, varying flow rate and other variables which can lead to deleterious results.

The Wild-Barfield research and development department at Watford, England, has now developed a drip-feed liquid mixture which is readily available and relatively cheap, and produces an atmosphere that is virtually free from decarburizing gases. Deleterious sulphur compounds are absent, undue sooting is avoided, the drip rate need not be critical, and the resultant atmosphere has a composition similar to that of P.T.G. so that it carburizes at the same rate and with the same diffusion characteristics. The liquid mixture has been trade-marked "Carbodrip." Table I shows that the resultant atmosphere is similar to P.T.G. and its carburizing potential is practically identical. A Carbodrip installation is illustrated in Fig. 4 and its caption.

Scale-free heating has made substantial progress in Britain and several units have gone into production. The so-called "non-scale" system uses relatively pure oxygen, and by partial combustion, sufficient hydrogen and carbon monoxide can be left in the products of combustion which bathe the work to counterbalance completely the oxidizing effect of the carbon dioxide and water. Sufficient heat is still derived from the burned gas to provide temperatures of 2200 to 2350° F. Such partial combustion with oxygen means that approximately half the heating value of the gas remains as unburned products.

In second-stage combustion (called secondary combustion) these products are burned with

Fig. 4 — Wild-Barfield's Carbodrip Gas Carburizing Installation. Furnace liner has a clamped top seal and a chrome-ore bottom seal. The door is raised by means of a hydraulic ram; efficient gas circulation is insured by a centrifugal fan at the bottom of the furnace, together with an inner drum located centrally on a throat casing. The carburizing liquid is fed into the furnace by low-pressure air, and a calibrated flowmeter gives a positive indication of the quantity of liquid entering the furnace

Table I — Comparative Analysis of Towns' Gas and "Carbodrip" Atmospheres

Constituents	Towns' Gas		"Carbodrip" Atmosphere
	Raw	Prepared	
Carbon dioxide	3.3%	0.0-0.2%	0.0-0.3%
Oxygen	0.6	0.0-0.1	0.0-0.2
Unsaturated hydrocarbons	2.1	0.4-0.6	0.2-0.6
Carbon monoxide	16.4	20.2	20.0-25.0
Methane	24.0	23.6	20.0-25.0
Hydrogen	49.5	51.2	58.0-48.0
Nitrogen	4.1	Bal.	—

Fig. 5 – Vibrator Tube Furnaces for Continuous Hardening of Small Components. At 1470 to 1560° F., each furnace has an output of approximately 15 lb. per hr. One operator can attend four furnaces, his work being limited to feeding the hoppers and removing finished work from the quench tank. Courtesy Wild-Barfield Electric Furnaces, Ltd.

air to preheat the work or stock up to, say, 1200° F., at which temperature no appreciable scaling occurs. The second-stage combustion takes place in the inlet zone of a continuous furnace – or in a preheating chamber if a batch furnace is used. Further recuperation of heat normally preheats the gas and oxygen for the primary combustion. The efficiency of combustion with oxygen is extremely high, due to the very small amount of heat taken out in the combustion products, which are only about 30% of the volume compared with normal combustion with air. The process is therefore more economical in gas consumption than a standard gas-fired furnace. Not only can oxidation be completely eliminated but if desired a controlled amount of oxidation can be obtained.

Saving in scale will often repay the cost of liquid oxygen. If a tonnage oxygen plant is available, then the process can be considered economical for what may be called the cruder heating operations, including soaking pits, slab reheating furnaces and large-scale heating operations in any steelworks. A gas-fired furnace can be designed to operate as a conventional unit, but can incorporate the non-scale process for use at will merely by changing over a simple system of valves.

One British furnace is being used to heat billets prior to extrusion, and a continuous furnace is installed for heating alloy steel billets for precision forging. Belgium has a continuous furnace for billet reheating for shell forging, and another continuous furnace is being installed in Germany. The first furnace in America is being built at the time of writing by Salem-Brosius, Inc., the American licencee.

The process has been used successfully in Great Britain for heating silicon steel billets for rolling, and there is no reason why electrical sheets could not be heat treated by this method. It has also been used successfully for stainless iron and several compositions of stainless steel, which oxidize rapidly above 2200° F. The increasing use of oxygen in steelmaking and treating plants will undoubtedly increase the adoption of this interesting process with many types of continuous and batch furnaces.

Vibrator Furnace – The continuous heat treatment of very small components often needs specially designed furnaces. Figure 5 shows the first of a battery of a dozen vibrator-tube furnaces designed to replace batch-type equipment. The chamber consists of a solid-drawn heat resisting tube held centrally in an outer tube, the annular space being filled with insulating materials. The exit end leads direct to a quench chute, the bottom of which is below the oil level of the quench tank. One end of the equipment is suspended in such a way that the angle of the tube can be adjusted to vary the feed rates. A Syntron vibrator fixed below the furnace casing provides the energy to pass the components through the tube; variation of the vibrator also varies the feed rate. Temperature control is provided by electronic controllers.

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Personal Mention

George Parkin

GEORGE PARKIN has recently completed his term as president of the Birmingham Metallurgical Society in England in its Golden Jubilee Year. Mr. Parkin joined that Society in 1946, subsequently becoming honorary editor of its monthly *Journal*, an office he has recently relinquished. It was during his tenure that the special Jubilee issue was published. Mr. Parkin's professional experience includes many years in the research department of a large steelworks. He also spent two years as chief metallurgist for a tool company, and has served as consultant to several steel, tool, and cutlery firms. In 1946 he joined J. B. & S. Lees, Ltd., and in 1953 was appointed director of research and development. Mr. Parkin writes that his "main hobby is musing about matters metallurgical and educational whilst sitting in front of a roaring coal fire (an old British custom). My wife has been – and still is – my constant companion and guide, and has presented me with two sons who can be classified as highly refractory material, with the latent energy of an uninhibited thermo-nuclear pile. They appear to be following in their father's footsteps in that they will most certainly mature very late – in fact, probably long after they should have reached the age of discretion."

H. W. Graham

HERBERT WINFIELD GRAHAM was recently appointed consultant on technology for Jones & Laughlin Steel Corp., Pittsburgh. He joined the corporation on his 23rd birthday in 1914, immediately after graduation from Lehigh University with a degree in electrometallurgy, going up through the ranks until 1947 when he was elected vice-president, technology. In 1953 he became vice-president in charge of research and development.

During the years Mr. Graham has supervised pioneering research into the effect of nitrogen in steel. It was he who conceived and developed the high-sulphur, intermediate-manganese steels which later became the X 1300 series, as well as the use of intermediate manganese steel for tank armor during World War II. He was one of the founders of the Industrial Research Institute, and served as its first full-time president. His travels for his company and the Government have taken Mr. Graham to 19 of the 21 republics of the Americas, to Africa, Arabia, India, China, and most of the countries of Europe. Among his publications are "The Machinability of Free-Cutting Steels", "The Acid Bessemer Process of 1940", "Development of Rotary Drill Pipe", and "Factors Which Determine Iron and Steelmaking Processes".

Alton Frank Davis

A. F. DAVIS, vice-president and secretary of the Lincoln Electric Co. of Cleveland, was awarded the 1954 Samuel Wylie Miller Memorial Medal by the American Welding Society "for outstanding contributions to the advancement of welding", including generous contributions to the promotion of welding education.

A native of Ohio (Alliance), "Charlie" Davis attended Mt. Union College and graduated from Ohio State University in 1914 with a degree of mechanical engineer in electrical engineering. He then started to work for Lincoln Electric Co., and was almost immediately made responsible for an educational and promotional program to develop the welding industry, to which he has devoted much time during the subsequent 40 years. Under his sponsorship and largely through his contributions, Ohio State University possesses what is probably the world's most extensive library on the various aspects of welding. In 1925 he was made a director and elected vice-president of Lincoln Electric, and in 1938 became vice-president and secretary. He is a member of the American Welding Society, American Society for Engineering Education, American Society for Agricultural Engineering, American Society of Mechanical Engineers, and American College Publicity Association. He became acquainted with innumerable ASMembers at the annual National Metal Expositions, where he is always the genial host at the Lincoln exhibit.

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Personals . . .

Raymond E. Wright is now district industrial heating specialist for the east central district, General Electric Co., Cincinnati, Ohio.

Irving A. Dickter, formerly supervisor of the flamatic laboratory, process machinery division of the Cincinnati Milling Machine Co., has been appointed field engineer in the flamatic department at the company's Chicago branch.

L. M. Taussig, formerly metallurgist for the Magnaflux Corp., Chicago, has formed the firm of Taussig Associates in the same city, offering metallurgical consulting and laboratory service, as well as complete chemical, physical and nondestructive testing.

Roy J. Davis, who graduated from the University of Maryland in June '54, is employed in the research department of the Bethlehem Steel Co., Bethlehem, Pa.

Kenneth I. Johnson has been transferred by the Allis-Chalmers Mfg. Co. as sales representative in the district sales division in Birmingham, Ala.

Leonard Jaffe, formerly head of the metals research branch at Watertown Arsenal, Watertown, Mass., has accepted a position as chief of the materials section, jet propulsion laboratory, at the California Institute of Technology, Pasadena, Calif.

Norman A. Gjostein, who graduated in June 1954 from Illinois Institute of Technology with a M.S. in metallurgical engineering, is now a graduate student in the department of metallurgical engineering at Carnegie Institute of Technology, Pittsburgh, where he is working toward a Ph.D. degree.

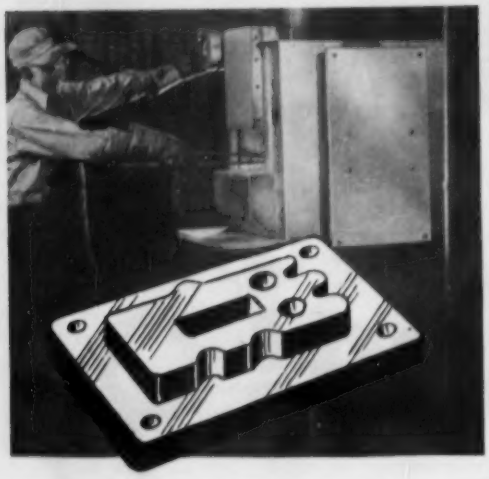
Robert A. Petrusek, a graduate of the University of Wisconsin, department of metallurgical engineering, in June 1954, is now working on the chemical metallurgical program for General Electric Co. and is on his second assignment at River Works, Lynn, Mass.

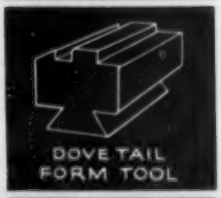
D. R. Green is now doing research in physical metallurgy with General Electric Co.'s applied research subsection, engineering department, at the installation which is operated by GE's Hanford Atomic Products Operation near Richland, Wash., for the Atomic Energy Commission. Mr. Green is a graduate of the University of Oregon, receiving his B.S. degree in physics in 1952, and was formerly a technical graduate on the rotational training program at Hanford.

Ernest R. Howard, after several years in charge of sales of thermostatic metal for the H. A. Wilson Co. of Union, N.J., has joined the Wade Electric Products Co., Sturgis, Mich., as development engineer on automotive electrical parts.

E. J. Mullarkey is employed as a physical metallurgist in the metallurgical laboratory, of the Arma Div., American Bosch Arma Corp., Garden City, N.Y.

Joseph M. Diskin has joined the sales force of the Duncan Steel Co., Detroit, as field representative in tool steels.





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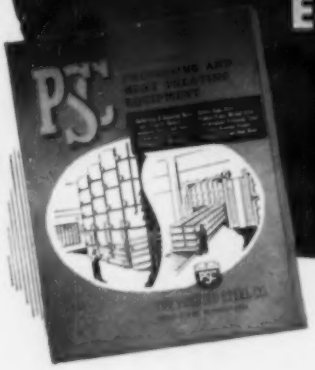

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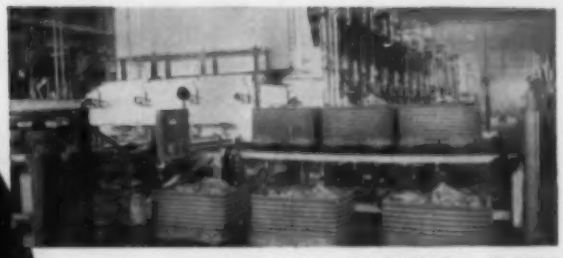

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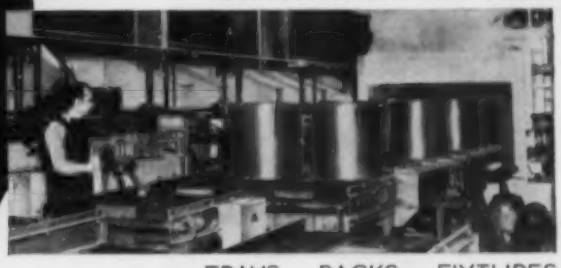

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Personals . . .

Robert H. Goodman, who has been stationed at Wright-Patterson Air Force Base with the Research and Development Command, was recently separated from the Air Force as first lieutenant. He has returned to E. I. du Pont de Nemours & Co., Inc., and is with the sales division of the electrochemicals department at the Niagara Falls, N.Y., plant.

John F. Heldehand has been transferred from the Midland, Mich., metallurgical laboratories of the Dow Chemical Co. to the Madison, Ill., division, and is assigned as a foreman in the finishing section of the rolling mill.

Thomas A. Curtis, formerly with the Newark, N.J., branch office of the Latrobe Steel Co., is now the Rochester, N.Y., sales representative with offices in Buffalo, N.Y.

Donald E. Haltar has left the U. S. Bureau of Mines, Albany, Ore., where he was employed as extractive metallurgist, to accept a position as metallurgist with Hanna Nickel Smelting Co., Riddle, Ore.

Dean D. Burgan has resigned as principal metallurgist at Battelle Memorial Institute, where he had been employed for 13 years, to assume the position of research metallurgist with the Electric Steel Foundry Co., Portland, Ore.

R. V. Cordingley, formerly chief tin mill metallurgist and inspector at the Fairless Works of United States Steel Corp., is now assistant superintendent of the metallurgical department at the Indiana Harbor Plant of the Youngstown Sheet & Tube Co.

Ralph E. Johnson has been transferred by the Townsend Co.'s Canadian affiliate, Parmenter and Bulloch Mfg. Co. Ltd., from Gananoque, Ont., where he was superintendent, to New Brighton, Pa., to become production engineer of the Townsend Co.'s main plant.

Frederick E. Johnson is now assigned as a rotational trainee in the process physics unit, Hanford Atomic Products Operation, General Electric Co., Richland, Wash.

Louis E. Coltenyahn has accepted a position with the Applied Research Laboratory of United States Steel Corp. after acquiring a Ph.D. in metallurgy at Pennsylvania State University.

Richard D. Lambert, who graduated from Michigan State College in August 1954 with a degree of B.S. in metallurgy, has accepted a position on the engineering staff of the Motor Wheel Corp., Lansing, Mich.

John Korthener has resigned as assistant engineer at Western Electric Co., Winston-Salem, N.C., to do graduate work in nuclear engineering at North Carolina State College.

Francis B. Foley has been detached from the Bayonne Laboratory staff of International Nickel Co., Inc., and assigned to the stainless steel section in New York City. Dr. Foley's title of consulting metallurgist remains the same.

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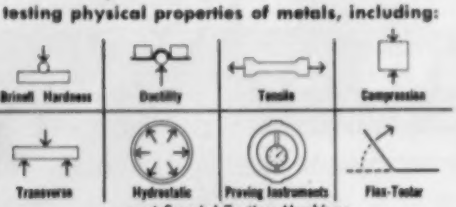

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Personals . . .

William P. Saunders has been promoted from research and development engineer in the metallurgical laboratories of Dow Chemical Co. to laboratory division leader, technical department, Madison, Ill.

R. K. Waldvogel, formerly tool planning engineer at Crosley Div., Avco Mfg. Corp., Richmond, Ind., is now welding engineer at Stromberg-Carlson Co., Rochester, N.Y.

Chin Tse Yang has resigned his teaching position at Massachusetts Institute of Technology and is now a research engineer in stress analysis at Ford Motor Co., Dearborn, Mich.

James A. Ndulue, who graduated in June '54 from the Montana School of Mines with a B.S. in metallurgical engineering, now holds a graduate teaching and research assistantship in the department of mineral dressing engineering at the same school.

William M. Justusson, formerly a nuclear engineer with Consolidated Vultee Aircraft Corp., Fort Worth, Tex., has accepted a position as research engineer with the Ford Scientific Research Laboratory, Dearborn, Mich.

Robert Tichane, on leave from Sylvania Electric Products, Inc., is completing his work for a Ph.D. in inorganic chemistry at the State University of Iowa.

S. Donald Pitts is now employed as a metallurgist at the Davenport, Iowa, works of the Aluminum Co. of America, having been released to inactive duty as a lieutenant (junior grade) from the U. S. Navy.

William J. Hendry has resigned his position as factory metallurgist for the John Deere Dubuque Co., and is now employed as technical engineer with General Electric Co., Aircraft Nuclear Propulsion Dept., Evandale, Ohio.

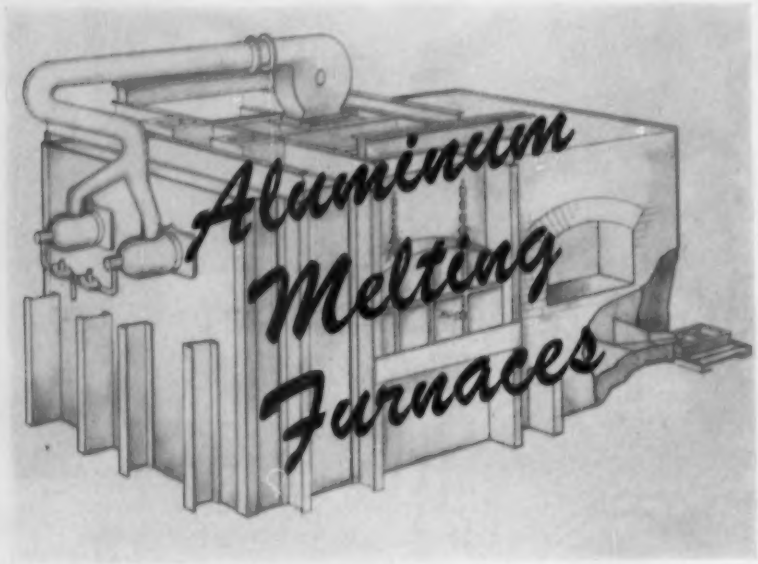
Peter A. Hassell, a former representative of Westinghouse Electric Corp., is now manager of the high frequency division, Magnethermic Corp., Youngstown, Ohio.

Helen Hoover has resigned as research metallurgist in the manufacturing research division of International Harvester Co., Chicago, and is now living in the Superior National Forest on a border lake, where she plans to fish, write, and assist in her husband's business at Grand Marais, Minn.

William J. Craig, formerly with Sandia Corp., Albuquerque, N.M., is now a research metallurgist at the central research laboratory of Borg-Warner Corp., Bellwood, Ill.

After 16 years as general sales manager of Peninsular Steel Co., Detroit, **Frank G. Davis** has retired. He spent a number of years with Atlas, Crucible, Carpenter, and Firth Sterling before joining the Peninsular organization.

Robert H. Dickinson, previously employed on research and development of titanium at P. R. Mallory & Co., Inc., is now working on the production of titanium and titanium alloy wire at National Standard Co., Niles, Mich.



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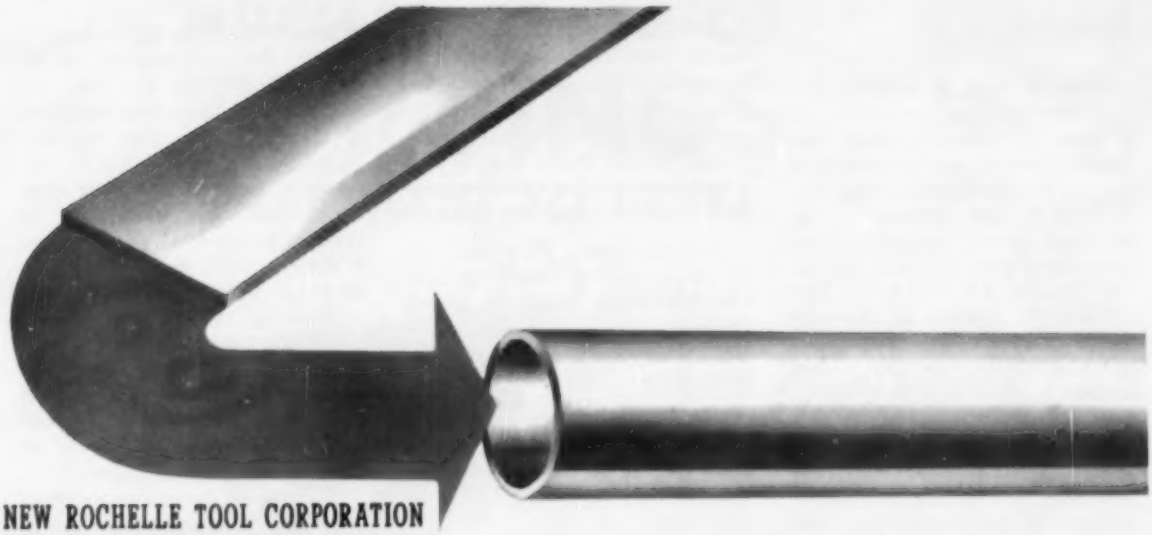


NEW ROCHELLE TOOL CORPORATION

Announces A FAR REACHING DEVELOPMENT IN

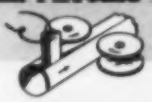
TUBE WELDING

A NEW, FASTER, SIMPLIFIED METHOD OF TUBE WELDING THROUGH HIGH FREQUENCY HEATING

If you make, sell or use tubing in any form, this announcement is of paramount importance to you. Now it is possible to manufacture tubing of various diameters from aluminum strip, steel or other metals, on a continuous basis inexpensively, quickly and simply.

The enthusiastic response of tube engineers, and orders placed by corporations who have seen confidential demonstrations of the Thermatool Method of tube welding, has been most gratifying. If you are interested, either for reconversion purposes or otherwise, demonstrable evidence of this new basic way to cut costs and increase tube production is available to you.

NO OTHER PROCESS LIKE IT!



- Pinpoint Heating — only the welded area is heated, not the rest of the tube.
- No change in weld head is required to change tube diameter or type of metal.
- Welding speed is independent of diameter of tube.
- Same welding unit welds aluminum, steel, stainless steel, copper and brass interchangeably.
- Lower power equipment and lower cost than by induction and other methods for the same production.

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Personals . . .

James P. Gill, national past president, who has been serving as president of Vanadium-Alloys Steel Canada Limited, is now chairman of the board of the Canadian Company. Mr. Gill is also president of the American parent company, Vanadium-Alloys Steel Co., Latrobe, Pa.

Ward W. Minkler, formerly Pacific Coast manager of sales and technical service, has been named assistant manager of market development of the Titanium Metals Corp. of America, assuming his new duties at the general sales office in New York City. Mr. Minkler received his bachelor of metallurgical engineering degree from Rensselaer Polytechnic Institute and his master of business administration from Harvard University. Prior to joining Titanium Metals, Mr. Minkler was employed by the Babcock & Wilcox Co., tubular products division, as a member of the metallurgy staff.

P. Leckie-Ewing, formerly in the employ of the Union Twist Drill Co., Butterfield Div., Rock Island, Quebec, is now chief metallurgist of the Landis Machine Co., Waynesboro, Pa.

John R. Sacks, previously with the Caterpillar Tractor Co., is now a metallurgist at the Sheffield Steel Div., Armco Steel Corp., Kansas City, Mo.

Reuel E. Warriner, in charge of sales to the steel industry for the International Nickel Co., Inc., has been appointed vice-president, sales, of Climax Molybdenum Co., New York City. A graduate of Yale University in 1933, Mr. Warriner spent the following two years with the Western Mining Corp. of Melbourne in the gold fields of West Australia. He joined International Nickel as an engineer in 1935, serving at the company's rolling mill at Huntington, W.Va., and later in its Washington, D.C., office. After a leave of absence during which he served with the Ordnance Department of the U. S. Army at Washington, D.C., he returned to International Nickel at its New York executive offices to supervise the sales of nickel to the steel industry.

George W. Belcher has been appointed central district manager of sales and technical service of the Titanium Metals Corp. of America, Chicago. Mr. Belcher is a graduate of Rensselaer Polytechnic Institute with a degree of B.S. in metallurgical engineering. He was formerly employed by Allegheny Ludlum Steel Corp., Watervliet, N.Y., where he held the position of production metallurgist, mill metallurgist and technical service representative.

Gerald G. Hatch, director of research for Quebec Iron and Titanium Corp. since 1952, has been appointed plant superintendent of the company's operations at Sorel, Que. Mr. Hatch had previously been research metallurgist with the Shawinigan Water and Power Co. in Shawinigan Falls, Que., and with Armour Research Foundation, Chicago. Succeeding him as director of research at Quebec Iron and Titanium is **P. J. Ensio**, research metallurgist with the company since February 1953.

George L. Hoobler has been promoted to the Pittsburgh technical field section of the development and research division of the International Nickel Co., Inc. Mr. Hoobler has been with International Nickel since 1947, when he joined the company as a member of the technical department at its works in Bayonne, N.J. He had been with the division's ductile iron section in New York from May, 1951, until his present appointment.

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Ames Portable Tester making hardness test on large casting while being machined.

You can get accurate, dependable tests anywhere, anytime, with Ames Portable Hardness Testers. No delays, no waiting for laboratory tests, no cutting off specimens. Anyone can operate.

Ames Testers are light in weight — may be taken to the work — read directly in the Rockwell Scales. Are made in sizes from 1" to 8" capacity for testing rounds, flats, sheet stock, tubing, odd shaped pieces and assembled parts.

Look into this time-saving, inexpensive method of making your hardness tests today. Thousands in every day use. Send for folder "Rockwell Hardness Testing Made Easy".

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ARE MADE TO LAST!

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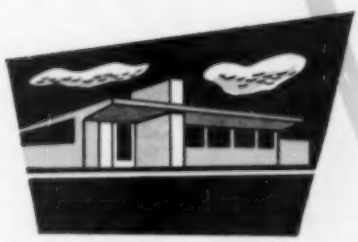

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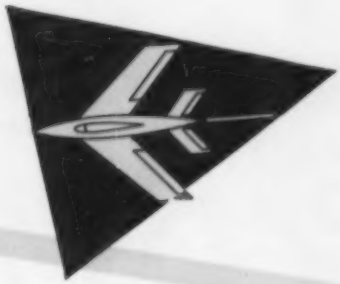
One of four Mueller Brass Co. parts in modern waste disposal unit. Completely dependable in daily operation.

WINDOW HARDWARE

Forged of natural bronze. Can be furnished in aluminum or chrome finish as desired. Retains original beauty indefinitely.

BURNER HEAD

Forged of aluminum for installation in gas stove. Lightweight yet strong.



IN AVIATION

TORQUE ARM LANDING GEAR SUPPORT MEMBER

These aluminum forgings provide the same strength as steel yet weigh only 1/3 as much. Smooth bright surfaces save machining time and eliminate costly finishing.

INSTRUMENT HOUSING

Specially designed forged housing for sealing diaphragm in aviation pressure warning unit.

IN INDUSTRY

CONNECTING ROD

Forged from "600" series metal. Over two million connecting rods produced without recorded failure.

ACTUATING GEAR

Forged from special Mueller Brass Co. alloy. Must take constant pounding.

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Forged of "600" series metal for use in automotive automatic transmission. Replaced part that was giving constant trouble; solved costly problem.

All Mueller Brass Co. forgings, of which just a few are shown here, have a dense, close-grained structure with a high tensile strength. Weight savings up to 40% are possible in the design of parts because of the close tolerances to which they can be produced. Less scrap and longer tool life result from the easy machinability of forged parts. Mueller Brass Co. is completely equipped to design parts for your products, specify alloys (including special alloys developed by our metallurgists), forge, machine, finish and plate the parts and perform all necessary assembly operations. Write today for our free illustrated 32-page forgings catalog and complete information about MBCo forged parts for your products.

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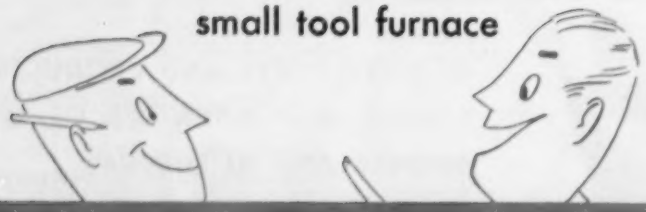
tool heat-treating
with a Waltz
small tool furnace



This WALTZ HEAT TREATING PLANT includes a pre-heat furnace, high heat furnace and quenth tanks, in a unit designed for convenient positioning in your shop. Furnace sections, equipped with casters, have temperature range permitting treatment of all high speed steels including cobalt.

Owning a Waltz Furnace eliminates (1) cost of sending out small parts, (2) materials-handling expenses, and (3) production delays caused by waiting for outside service.

A complete line of Waltz standard or special heat-treating furnaces, using all types of fuels, are built to suit your requirements.

Waltz FURNACE COMPANY
SYMMES STREET • CINCINNATI, OHIO

Write today to Dept. W for comprehensive bulletin.

Personals . . .

Truxtun R. Brodhead is now employed as eastern sales representative for Cameron Iron Works, Inc., Houston, Texas, covering the area east of Pittsburgh.

Walter Kilimnik has been named sales manager of Solar Steel Corp. of Calif., and will direct all sales and customer service in Calif.

Seymour J. Sindeband has been elected president of the Teleregister Corp., Stamford, Conn. Mr. Sindeband leaves the presidencies of Mercast Corp. and its affiliate, Alloy Precision Castings Co., with whom he has been associated since 1950. Prior to that he served five years as technical director and assistant to the president of American Electro Metal Corp., Yonkers, N. Y.

A. J. Gillespie retired on his 65th birthday as chief metallurgist at Thew Shovel Co., Lorain, Ohio. For the past 24 years, Mr. Gillespie has done all purchasing of metal for the company's products.

Birger Egeberg has retired as technical consultant and chief metallurgist for International Silver Co., Meriden, Conn. Previously with Crucible Steel Co., Dr. Egeberg was also associated with the steel and nonferrous industries in Scandinavia and Germany. He graduated as a mining and metallurgical engineer from the University of Oslo, and received his doctor's degree in metallurgy from Aachen University. Dr. Egeberg plans to do consulting work in development and research, with an office in Meriden.

E. S. Steigner, who has 20 years' service with the Youngstown Sheet and Tube Co., Youngstown, Ohio, has been appointed supervisor of the company's newly organized service engineering department. Mr. Steigner joined Sheet and Tube as a tester in the metallurgical laboratory in 1934 after receiving his master's degree in metallurgical engineering at Case Institute of Technology. Subsequently he was named assistant metallurgist and metallurgist, and in 1949 he was transferred to the research and development department as a tubular development engineer and later as a metallurgical engineer.

Cut metal-treating costs 55% with Armour Ammonia!

This cost comparison chart illustrates how you can make this great saving by switching to pure, dry Armour Ammonia, as a source of hydrogen!

	HYDROGEN	ARMOUR AMMONIA	REMARKS
Delivered base price	$2.00 per cyl.	$18.50 per cyl.	
Volume per cylinder	200 cu. ft.	4500 cu. ft.	After dissociation
Equivalent number of cyls.	23	1	
Handling labor (5¢/cyl.)	$1.15	$.05	
Storage cost (4¢/cyl.)	.92	.04	
Handling labor/100 cu. ft.	.025	.001	
Storage cost/100 cu. ft.	.020	.001	
Cost of product/100 cu. ft.	1.00	.410	
Cost of equipment/100 cu. ft.	—	.125*	Amortized in 3 years
Cost of electric power/100 cu. ft.	—	.060	
Total cost/100 cu. ft.	$1.045	$.597	
Savings in operation/100 cu. ft.		.448	

Percentage savings in operation cost 44%

and after equipment is amortized, savings are . . 55% †

*This figure arrived at by the following assumption: 500 cu. ft.- per hour dissociator costs approximately $4500 installed. Assume equipment to be completely amortized in 3 years, then amortized cost of equipment equals $.125 per 100 cu. ft.

DATA COURTESY THOMAS GAS CONTRACTORS, WESTFIELD, N. J.

Let Armour Help Solve Your Metal Treating Problems

Manufacturers get more than ammonia when they specify Armour. Since 1947 Armour has sponsored a fellowship at a leading technological university for the study of metal treating processes using ammonia. The results of this research are available to you. Furthermore, the men of the Armour Technical Service Department are equipped to handle and answer any problems arising with ammonia installations for metal treating. Write today for free copies of the booklets offered at right. If your problems are unusual or pressing, write, giving full details.

† Additional savings are possible when you order tank truck quantities — service available in most areas.

CLIP AND MAIL THIS TODAY!

Please send me free copies of the booklets which I have checked:

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P 1

ARMOUR

Ammonia Division

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Personals . . .

Niles R. Pettey, formerly erection engineer for Electric Furnace Co., Salem, Ohio, is now furnace engineer, in charge of maintenance and operation of furnace equipment, for American Brass Co., Waterbury, Conn.

David F. Dickinson has joined the chemical engineering staff of the University of Tulsa and is in charge of the metallurgy course.

Henry J. Fisher has joined the staff of the materials and processes section of the General Electric Co., Research Laboratory, Schenectady, N.Y. Dr. Fisher was formerly with the Physical Metallurgy Div., Department of Mines and Technical Surveys, Ottawa, Canada.

Francis J. Dragun, a graduate of Drexel Institute of Technology with a B.S. degree in metallurgical engineering, is now employed as metallurgical assistant by Kaiser Steel Corp., Fontana, Calif.

John H. Hoke, previously an instructor in the School of Engineering at Johns Hopkins University, is now employed as metallurgist at the Research Center of Babcock & Wilcox Co. in Alliance, Ohio.

Carl A. Harmon has retired as chief metallurgist with the Hanna Furnace Corp., Buffalo, N.Y., and will soon open an office in Detroit as foundry consultant.

R. D. Lindner and **Don C. Sellar** have joined the staff of Metallurgical Products Co., Brookline, Mass. **R. H. Harrington** is also engaged as metallurgical consultant for the company.

John E. Haig, formerly vice-president and secretary of Ajax Electric Co., Philadelphia, has been elected president of the company. **Leon B. Rosseau** was re-elected vice-president.

James H. Moore has been appointed general manager of Vacuum Metals Corp., jointly owned by Crucible Steel Co. of America and National Research Corp., with offices in Syracuse, N.Y. Mr. Moore, a graduate of Massachusetts Institute of Technology, became associated with the Aluminum Co. of America after leaving college. In June 1946 he joined the National Research Corp. as research and development metallurgist, and in 1948 he became director of the metallurgical department. When Vacuum Metals Corp.'s activities were expanded in 1953, Mr. Moore was appointed manager.

Howard Biers, New York consulting engineer, has been awarded the degree of Dr. mont. (Doctor of Mining and Metallurgy) of the Montanistische Hochschule, Leoben, Austria. Earlier this year Mr. Biers was formally elected president of the International Institute of Welding.

Gerald W. Hulit, who graduated from Rensselaer Polytechnic Institute last June with a B.S. in metallurgical engineering, is employed as metallurgist at Wright Aeronautical Corp., Wood-Ridge, N.J.

Warren H. Friske, previously employed as metallurgist at the Naval Research Laboratory, Washington, D.C., has accepted a position as senior engineer with the atomic power division of Westinghouse Electric Corp., Pittsburgh.

Standard or Special Design

YOUNG BROTHERS OVENS

solve your heat-treating problems

Electrically heated, controlled atmosphere, rack-type magnesium alloy heat treat ovens.

Every Young Brothers Oven, whether standard type or special design, is engineered to meet the most exacting requirements. Leading manufacturers processing ferrous or non-ferrous metals are finding that Young Brothers Ovens improve the quality of their products at considerable savings in time and money. Many branches of the Armed Services, too, have approved the use of Young Brothers Ovens where heat treating applications are required.

For over 50 years, Young Brothers Company has continually developed batch and conveyor ovens for new processes, materials and products where heating requirements are not in excess of 950° F. The dependability of these ovens in thousands of installations is your assurance of finest results at lowest cost. Experienced engineers are available for consultation without obligation. Write for Bulletin 14-T on heat treating.

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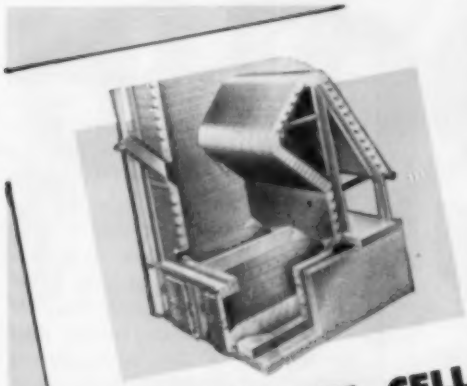
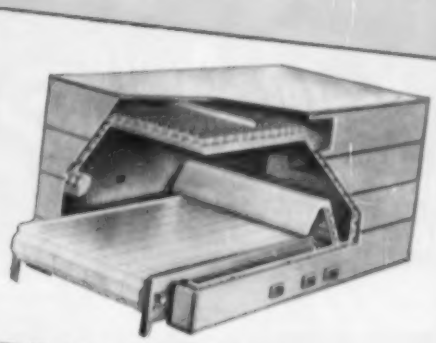


MOIST FUEL CELLS

An important application of B-L unit-suspended walls and arches is found in furnaces where a fuel with a high moisture content is burned. Although designed primarily for use in cane sugar countries for bagasse burning, these furnaces have proven so successful in other fields such as the burning of bark and wet wood refuse.

BIGELOW-LIPTAK *Corporation*

UNIT-SUSPENDED WALLS AND ARCHES



DRYER FURNACES

A tough assignment for a furnace is to stand up under the every-day beating of heat in drying applications. B-L's streamlined thin wall dryer furnace does it—cuts maintenance to boot. It furnishes heat for drying coal, sugar, salt, lumber, chemicals.

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LOWEST MAINTENANCE

Castable Linings

B-L's castable lining for oil refining furnaces provides a smooth monolithic wall capable of resisting abrasion and standing up under high heat demands. The construction is adaptable to catalytic regenerators, catalytic reactors, cyclones, stacks and other refinery equipment.

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UNIT-SUSPENDED WALLS AND ARCHES

When you specify a B-L furnace enclosure you can be sure of long life and lowest possible maintenance. Intelligent engineering and top-quality materials provide the stand-up stamina that makes enclosures "tougher than blazes." Each unit is individually designed for the job. Write today for complete information.

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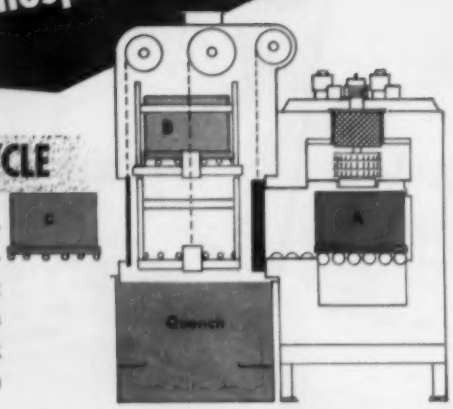
Sealed Cycle.....

A Dow Furnace FIRST for Batch-type controlled atmosphere furnaces.

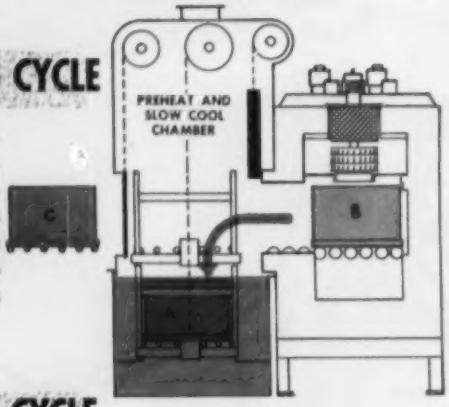
Step 1–LOADING CYCLE

Box A containing full furnace load of parts processing in work chamber. Box B—fully loaded, pre-heats in the upper vestibule. Box C—fully-loaded, waits on conveyor.



Step 2–QUENCHING CYCLE

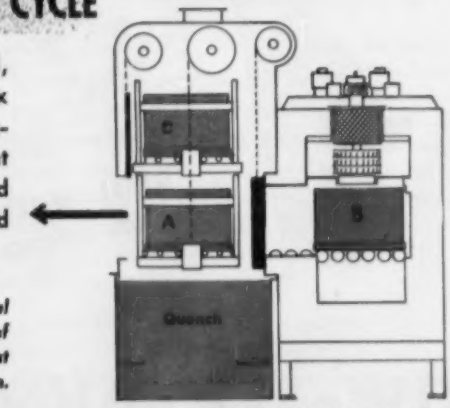
Box A completely processed, moves out to elevator and is lowered into quench; bringing pre-heated Box B to loading level. Box B is pushed into heat chamber and door is closed.



Step 3–RELOADING CYCLE

After proper interval, outer door is opened. Box C is placed on upper elevator and raised to pre-heat position as Box A is lifted from quench and removed from lower elevator.

Sealed Cycles' double door seal affords complete flexibility of processing without exposing heat chamber to air contamination.



Upper vestibule is easily adapted for slow cooling. Quench is adaptible for interrupted quenching.

DOW FURNACE COMPANY

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First WITH MECHANIZED, BATCH-TYPE, CONTROLLED ATMOSPHERE FURNACES

Personals . . .

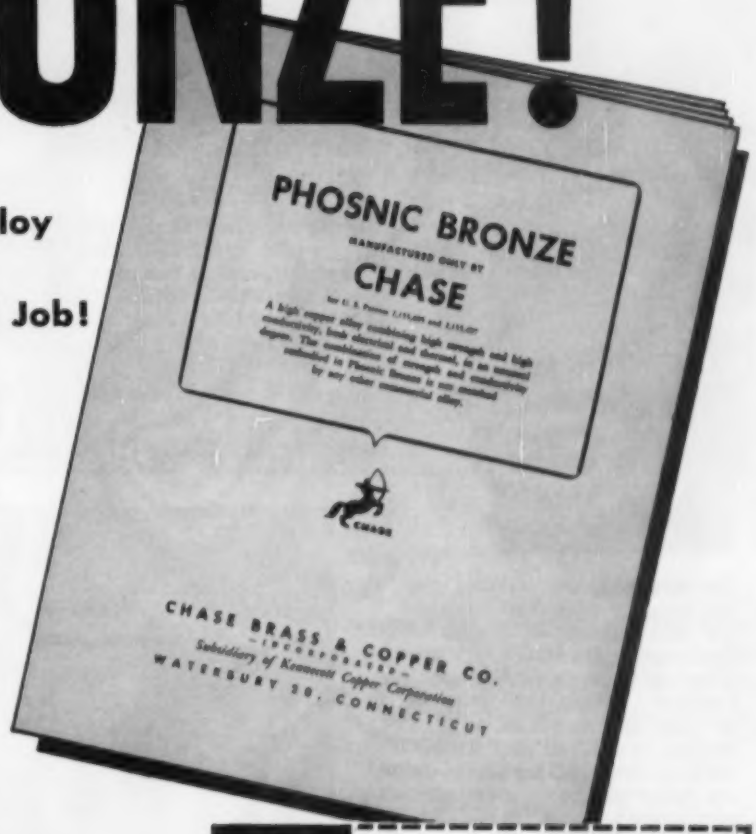
Alfred H. Lewis has been appointed sales manager of Vacuum Metals Corp., a company jointly owned by Crucible Steel Co. of America and National Research Corp., with headquarters at the new plant in Syracuse, N.Y. After leaving Syracuse University, Mr. Lewis entered the metallurgical department of the Sanderson-Halcomb Works of Crucible Steel and later became chief metallurgist. In 1947 he transferred to the sales department as sales service engineer, and in 1951 became branch sales manager for the central New York area, the position he held until his new assignment with Vacuum Metals Corp.

Paul Zeigler, director of Kaiser Aluminum and Chemical Corp.'s department of metallurgical research, has transferred from Spokane, Wash., to the company's headquarters at Oakland, Calif., which will permit him to work more closely with the company management although his responsibilities will remain the same. **Dana W. Smith**, associate director of the department of metallurgical research at Spokane, will assume the duties of laboratory manager in addition to those of his present post, and **S. E. Maddigan**, head of the mechanical evaluation section, has been made assistant director of the department, a post which is in addition to the present position of assistant director held by **L. W. Eastwood**.

William H. Sparr, Jr., formerly of Pittsburgh, has been transferred to New York and is in charge of the steel section of the nickel sales department of the International Nickel Co., Inc. Joining the company in 1946, Mr. Sparr was assigned to steel matters in the development and research division, and prior to his present appointment was head of the development and research division's technical field section. He is a graduate in metallurgical engineering of the Colorado School of Mines.

Garth S. Thompson, who has been with Misco Fabricators, Inc., Detroit, formerly a division of Michigan Steel Casting Co., for the past 11 years, has been made president and general manager.

PHOSNIC® BRONZE!



This patented Chase alloy may be the perfect metal for your Special Job!

For jobs requiring a metal with high strength as well as high conductivity, Chase Phosnic Bronze is ideal.

The combination of high strength and high conductivity found in Chase Phosnic Bronze *is not matched by any other commercial metal!* In addition, Chase Phosnic Bronze has excellent workability, high corrosion resistance.

For complete information on this special Chase alloy, check the coupon below.

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Personals . . .

Eugene M. Smith has been appointed assistant director of research at Lukens Steel Co., Coatesville, Pa. Mr. Smith was previously with Youngstown Sheet and Tube Co., Youngstown, Ohio, where he was development engineer in the mill research and development department. Prior to that he was research engineer at Battelle Memorial Institute in Columbus, Ohio.

George B. McMeans, vice-president in charge of operations for the Kaiser Steel Corp., has moved his offices from the Fontana, Calif., plant to the company's executive offices in Oakland, Calif.

Ray P. Dunn has been named director of metallurgy for both the East Chicago, Ind., and Toledo, Ohio, plants for the U. S. Reduction Co. Mr. Dunn was formerly plant metallurgist at the Chicago plant of the Doehler-Jarvis Division of the National Lead Co.

Hiram Brown, chief metallurgist of Solar Aircraft Co., Des Moines, Iowa, has been chosen to present the 1955 International Exchange Paper to the Institute of British Foundrymen. Mr. Brown's paper will be given at the International Foundry Congress to be held in London, England, in June 1955, and will be entitled "An Evaluation of Casting Methods".

C. L. Kessler has been appointed chief metallurgist at the Massena, N.Y., works of Aluminum Co. of America. A graduate of Rensselaer Polytechnic Institute, Mr. Kessler has had 17 years' service with Alcoa, and since 1951 has been assistant chief metallurgist at the Edgewater, N.J., works, the position he held at the time of his new appointment.

V. H. McBride, formerly quality control manager for the Wallace Aviation Corp., Wallingford, Conn., has been appointed manager of manufacturing.

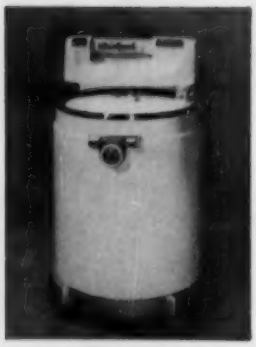
Hanns J. Maier, formerly dynamic test engineer at Chance Vought Aircraft, Inc., Dallas, Texas, is now assistant professor of structures at Instituto Tecnologico de Aeronautica (aeronautical engineering school operated by the Brazilian Air Ministry), Sao Jose dos Campos, Brazil.

Henry R. Friedberg has joined the Frank L. Crobaugh Co., Cleveland, as metal finishing consultant.

Lewis E. Thelin, formerly mill products engineer at the Scovill Mfg. Co., Waterbury, Conn., has accepted a position as assistant chief metallurgist for the Bristol Brass Co., Bristol, Conn.

C. T. Haller, Jr. has been placed in charge of the Pittsburgh technical field section of the development and research division of the International Nickel Co., Inc. Mr. Haller joined the company in January 1943 as a member of the Pittsburgh technical field section, and in 1951 was appointed in charge of the Cincinnati, Ohio, technical field section.

William L. Frankhouser is now employed at the atomic power division of Westinghouse Electric Corp., Bettis Field, Pa.



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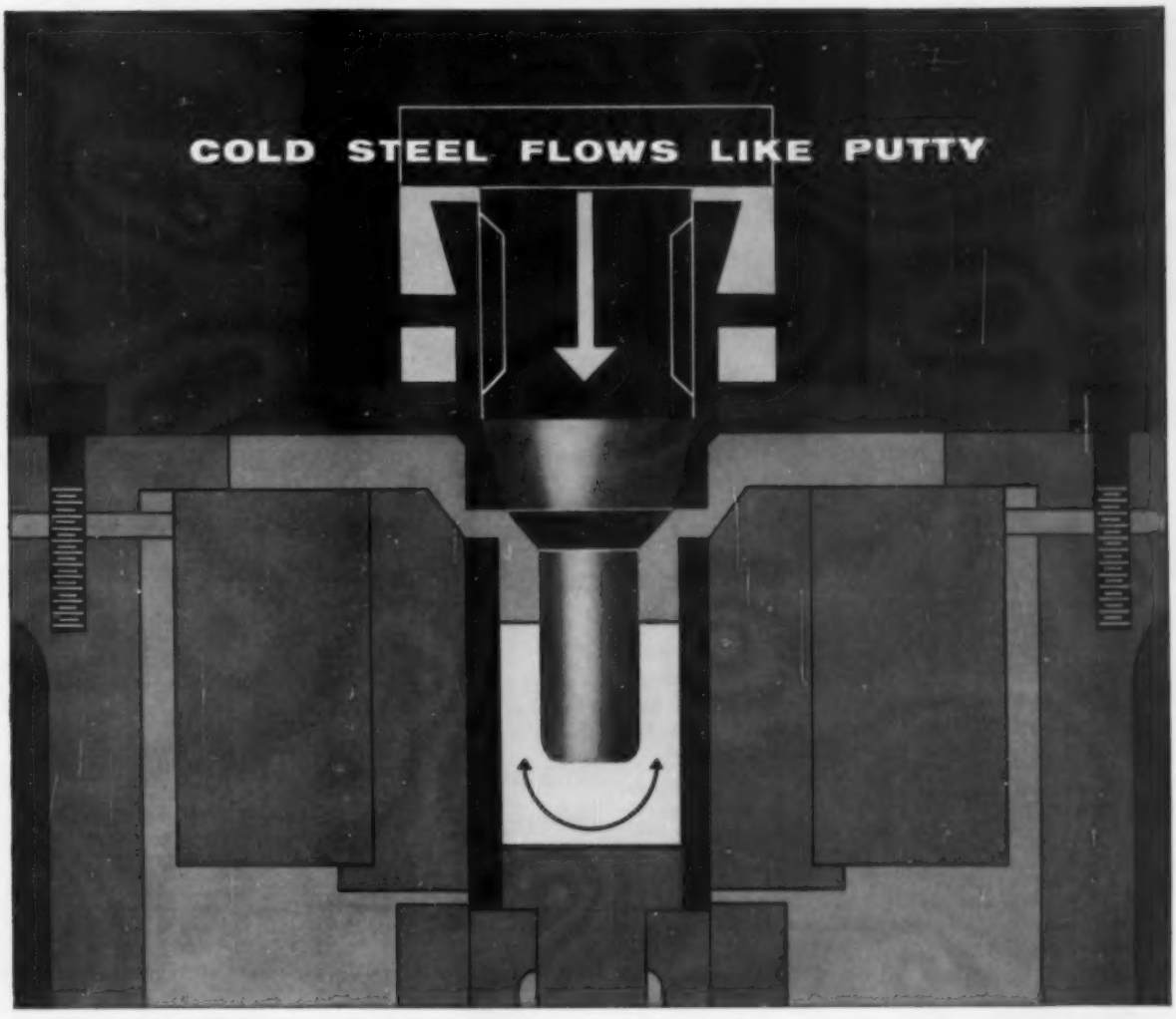

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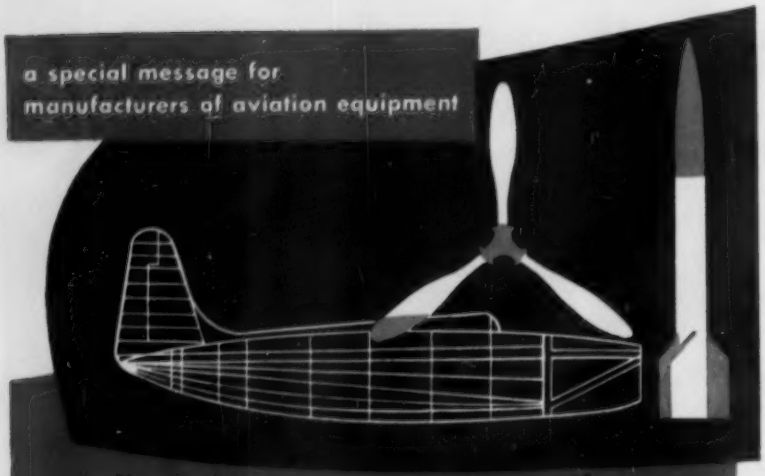

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Brittleness in Aluminum Alloys*

THE EFFECTS of composition, heat treatment, cold work and structure on the brittleness and mechanical properties of alloys of the British H 10 type were studied. These are wrought, heat treatable, aluminum-magnesium-silicon alloys with Mg_2Si as the precipitation-hardening constituent. Principal variations in composition were in magnesium and silicon contents, from 0.27 to 2.10% for the former and 0.24 to 1.54% for the latter. The effects of iron, manganese, chromium and copper were also studied briefly.

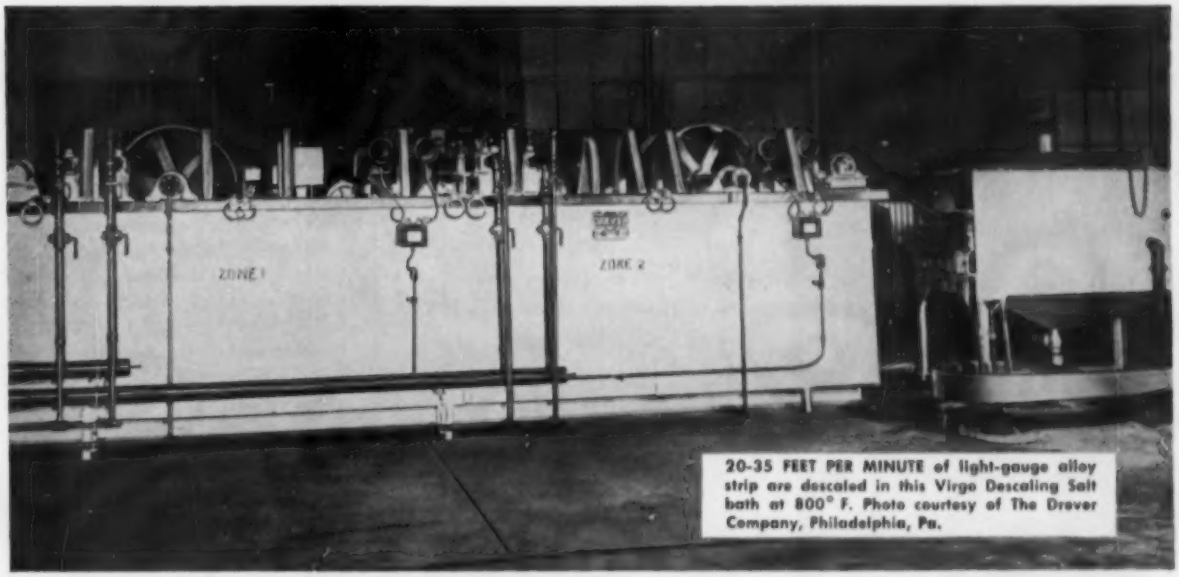
The alloys were prepared from aluminum of super-purity or 99.5% purity and fabricated as 0.036-in. thick sheet and ¾ and ⅝-in. diameter rod. The sheet was fabricated from 12 x 6 x 1-in. ingots cast by a semi-continuous process. The 0.25-in. diameter rod was extruded from 1¾-in. diameter continuously cast billets and the 0.5-in. diameter rod from 5-in. diameter billets. Solution heat treating was done in a circulating air furnace at 1000° F. After quenching, a precipitation hardening treatment of 8 hr. at 345° F. was employed.

The relative brittleness of the sheet alloys was evaluated by a free-cone bend test employing bend radii from zero thickness to 3½ times the thickness of the sheet. Sheet specimens free from cracking were classified as ductile, those with surface cracks usually as transition, and those with definite cracking and separation as brittle. The brittleness of extruded rod was evaluated by the Izod impact test; a minimum value of 11 ft-lb. was selected as a reasonable division for ductile and brittle alloys.

Results of the various tests showed that the properties of the alloys were dependent on both magnesium and silicon contents. Lines of equi-strength in the Al-Mg-Si system were hyperbolic in shape with the vertices directed toward the aluminum corner of the diagram and the asymptotes roughly parallel to the silicon axis and Mg_2Si line. In commercial-purity alloys, maximum strength and minimum alloy content were realized

(Continued on p. 180)

*Digest of "Factors Influencing Brittleness in Aluminum-Magnesium-Silicon Alloys", by I. R. Harris and P. C. Varley, *Journal of the Institute of Metals*, Vol. 82, p. 379-383.



20-35 FEET PER MINUTE of light-gauge alloy strip are descaled in this Virgo Descaling Salt bath at 800° F. Photo courtesy of The Drever Company, Philadelphia, Pa.

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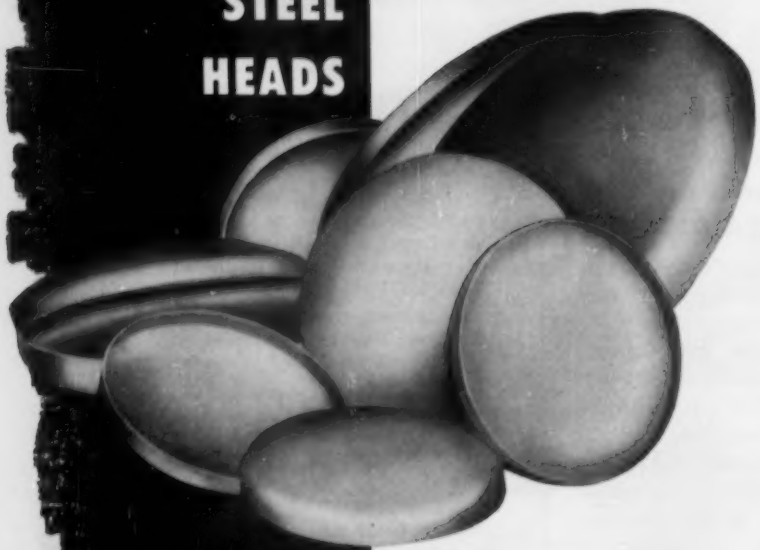

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Brittleness . . .

when the silicon content was about 1¾ times greater than that necessary to form the stoichiometric compound Mg_2Si. Slightly less silicon was required in super-purity alloys. Ductility varied approximately inversely with strength; in the high-purity alloys, brittle behavior was obtained with magnesium in excess of about 0.35% when silicon was 1.2% or greater, and with magnesium contents of 0.7% or higher when silicon was in excess of that necessary to form the compound Mg_2Si. The presence of iron in the commercial-purity alloys appeared to reduce the effective silicon content, shifting the regions of brittle behavior and high strength to higher silicon contents.

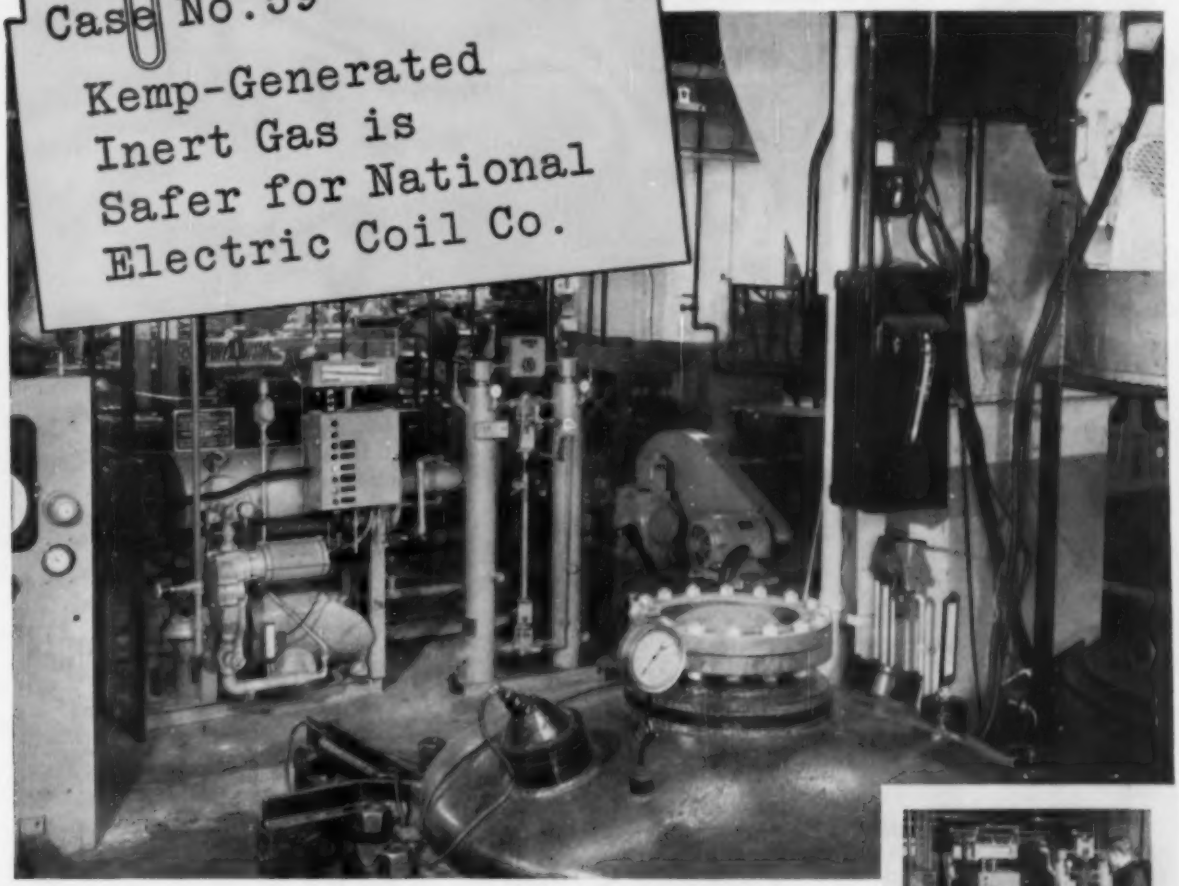
Microscopic examination revealed that maximum brittleness probably was associated with the preferential grain boundary precipitation of either free silicon or Mg_2Si or both, to form a continuous network. The brittleness of the alloy was determined by the relative strengths of this network and the grains. The weaker the network in comparison with the grains, the greater was the brittleness. Brittleness was also influenced by the length of path which the crack traveled at the grain boundaries. Extruded rod with greatly elongated grains tended to be less brittle than rod with equi-axed grains; however, moderate variations in the grain size of the equi-axed products had little effect on brittleness.

The continuity of the grain-boundary network varied with the composition and with heat treating and aging conditions. Within limits, the higher the solution heat treating temperature, the greater was the amount of alloying element in solution and the greater the precipitation at grain boundaries on aging. The continuity of the grain-boundary precipitate was also influenced by the rate of cooling from the heat treating temperature. The slower the rate of cooling, the greater was the amount of precipitation at the boundaries. This precipitation had little effect on the brittle behavior of alloys in the brittle range of compositions but did have a serious embrittling effect on compositions outside this range. Additions of copper

(Continued on p. 182)

Case No. 59

Kemp-Generated Inert Gas is Safer for National Electric Coil Co.



How National eliminates danger of explosion . . . cheaply and conveniently

National Electric Coil Co., Columbus, Ohio, impregnates electric coils and windings by forcing in a hot sealing compound with inert gas under pressure. Formerly, the Company used air under pressure, but this created an explosion hazard. National then switched to CO_2 generated by melting dry ice. Although this decreased the danger factor, it was an extremely expensive operation and very inconvenient. To modernize this process and cut costs, National installed a Kemp Gas Generator, Model MIHE.

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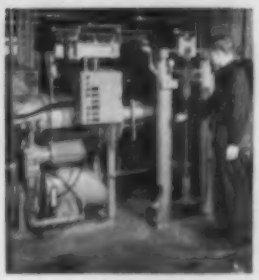
Every Kemp Generator is engineered for fast-starting, easy operation that saves both *time* and *money*. Kemp equipment delivers a chemically clean inert at a specific analysis . . . without fluctuations regardless of demand. And every Kemp design includes the latest firechecks and safety devices. For convenience, safety, and cleaner, more dependable gas—specify Kemp.



Mr. Wm. C. Graessle, of the engineering department, checking the operation. Generator features the Kemp Carburetor, part of all Kemp equipment, to deliver complete combustion . . . without waste, without tinkering.

For more complete facts and technical information, write for Bulletin I-10 to: **C. M. KEMP MFG. CO., 405 East Oliver Street, Baltimore 2, Md.**

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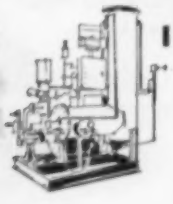

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Brittleness . . .

appeared to promote grain-boundary precipitation in slowly cooled alloys.

Tests showed that materials heat treated, quenched and naturally aged were not brittle; artificial aging caused grain-boundary precipitation and brittleness. Stretching before artificial aging had no effect on brittleness, although strengths increased significantly. Additions of manganese (0.4 to 0.7%) and chromium (0.2 to 0.3%) tended to suppress grain-boundary precipitation with the result that such alloys were less brittle and less notch-sensitive. Rapid quenching of such alloys is necessary, however, to suppress precipitation during cooling and to obtain maximum strengths on aging. Alloys with manganese and chromium are apt to have larger grain sizes.

W. A. ANDERSON

A Method of Controlling Quenching in Baths*

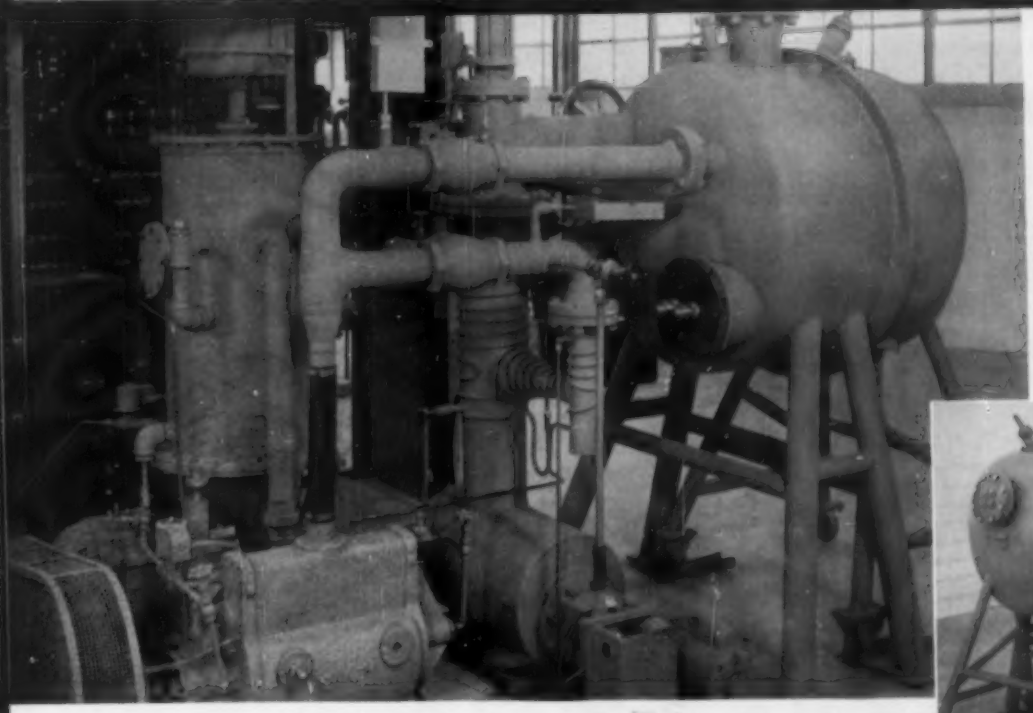
PART I of this article (*Metal Progress* for November, 1954, p. 187) demonstrated that the notched-bar impact strength and proportional limit (0.01% yield strength) of austempered steels were especially sensitive to the degree of completion of the bainite reaction. Complete transformation (99.5% or better) also resulted in a higher fatigue limit than incomplete transformation.

To determine the degree of completion of austenite transformation, dilatometric measurements gave the most reliable results. Plotting dilation against time on a logarithmic-autocatalytic graph paper facilitated the interpretation of the data. In Part I, the author suggested that structural heterogeneity probably lowered the mechanical properties. He showed that the properties of bainite were impaired by the presence of various proportions of martensite, either alone or together with retained austenite.

In the first section of Part II, the

(Continued on p. 184)

*Digest of "Factors Influencing the Isothermal Transformation of Austenite in the Intermediate Range (Bainite Range). Part II", by Otto Schaaber, *Draht* (English edition), April 1954, p. 29-39.



The stainless steel shell of the new CVC high vacuum laboratory furnace is 36" in diameter by 38" long. The shell has a bridge-breaker, a 1" sight tube over the crucible, a 6" window at eye-level for general observation. The whole unit is 6½-feet high and requires 90 sq. ft. of floor area. Inset shows working area.

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2. You perform general observations, alloy additions, tilt pouring, optical and/or thermocouple temperature measurements, bridge-breaking, pressure readings, and high frequency control *all from one spot*.

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4. You have a choice of five crucible sizes to accommodate melts of 5, 12, 17, 30 or 50 pounds.

5. Pre-pouring pressures range from 1 to 10 microns for a 50-pound melt of steel; correspondingly lower pressures are obtained when making smaller melts.

For detailed specifications on this new *CVC* laboratory vacuum furnace and for information on pilot or production type vacuum furnaces, write ***Consolidated Vacuum Corporation, Rochester 3, N. Y.*** (a subsidiary of Consolidated Engineering Corporation, Pasadena, California).

Typical performance of the new CVC high vacuum laboratory furnace with pumping system at normal heater input.

PRESSURE: Microns Hg	SPEED: Liters/Sec.	THROUGHPUT: Micron Liters/Sec.	THROUGHPUT: Micron Cu.Ft./Min.
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1.0	660	660	1,400
5.0	750	3,750	7,970
10.0	600	6,000	12,750
50.0	120	6,000	12,750
100.0	60	6,000	12,750

(Selective throughputs may be obtained by using the high, medium, and low heater switch mounted on the KS-600 pump.)

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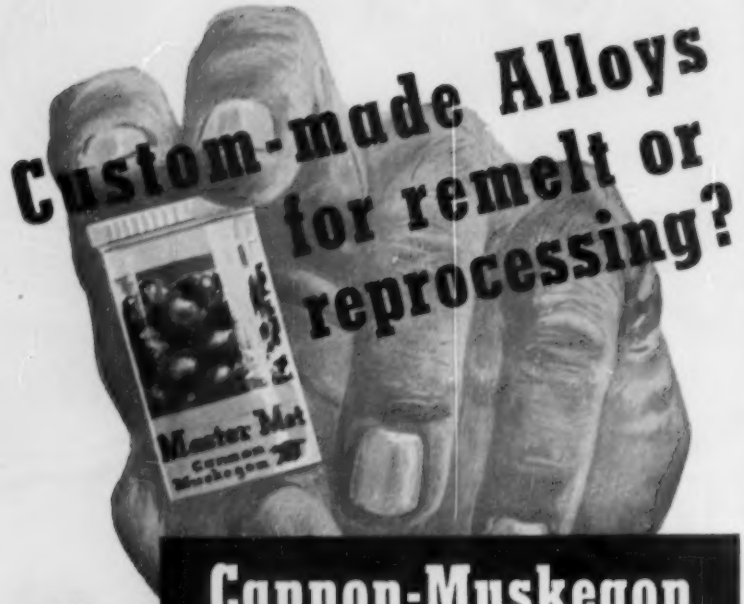

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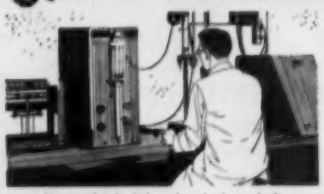
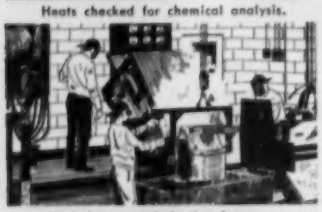


Heats checked for chemical analysis.



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METALLURGICAL SPECIALISTS

Bainite Reaction . . .

author attempts to demonstrate that the mechanical properties of bainite also are impaired by the presence of propearlitic ferrite, alone or together with pearlite. In the second section, he demonstrates how difficult it frequently is to avoid bainite transformation during martempering; he reports some interesting and unique experimental results of dilatometric measurements obtained during martempering at various temperatures and comments on their significance.

Nine dilatometer specimens of a manganese-vanadium steel with 0.36% C, 1.7% Mn, 0.16% Cr and 0.12% V, were austenitized at 1425° F. and transformed at 625° F. for 15 to 30 min. Four were transformed directly; the rest were air cooled 10 to 20 sec. before immersion in the transformation bath. Transformation during air cooling was clearly revealed by the dilatometer curves, and tensile tests showed progressive impairment of the mechanical properties with longer air cooling.

In practical austempering, transformation during air cooling is unlikely, but slack quenching preceding the bainite reaction is not uncommon (because of the low quenching power of hot salt baths) and causes similar heterogeneity due to high-temperature transformation. As an illustration, impact test pieces of 50 CrV 4 steel (an aeronautical standard steel; analysis not reported) were austempered at 635 to 645° F. in a nonagitated salt bath and in lead. The resulting hardness was Vickers 430 to 460, and 480 to 490, respectively; the impact strength was 233 to 280 ft-lb. per sq.in. for notched-bar samples treated in the baths. An agitated salt bath at 610° F. gave the same (lower) fatigue strength as the still salt, the same (higher) hardness as the lead bath and unchanged notched-bar impact strength.

Austempering in salt at 250 to 260° F. for 35 to 60 min. raised the fatigue limit to 68,500 psi. as against 55,000 psi. for the lead bath at 635 to 645° F. (REVIEWER'S REMARK: The increase is ascribed to the suppression of high-temperature transformation, but the explanation might well be questioned on the grounds that the hardness simultaneously

(Continued on p. 186)

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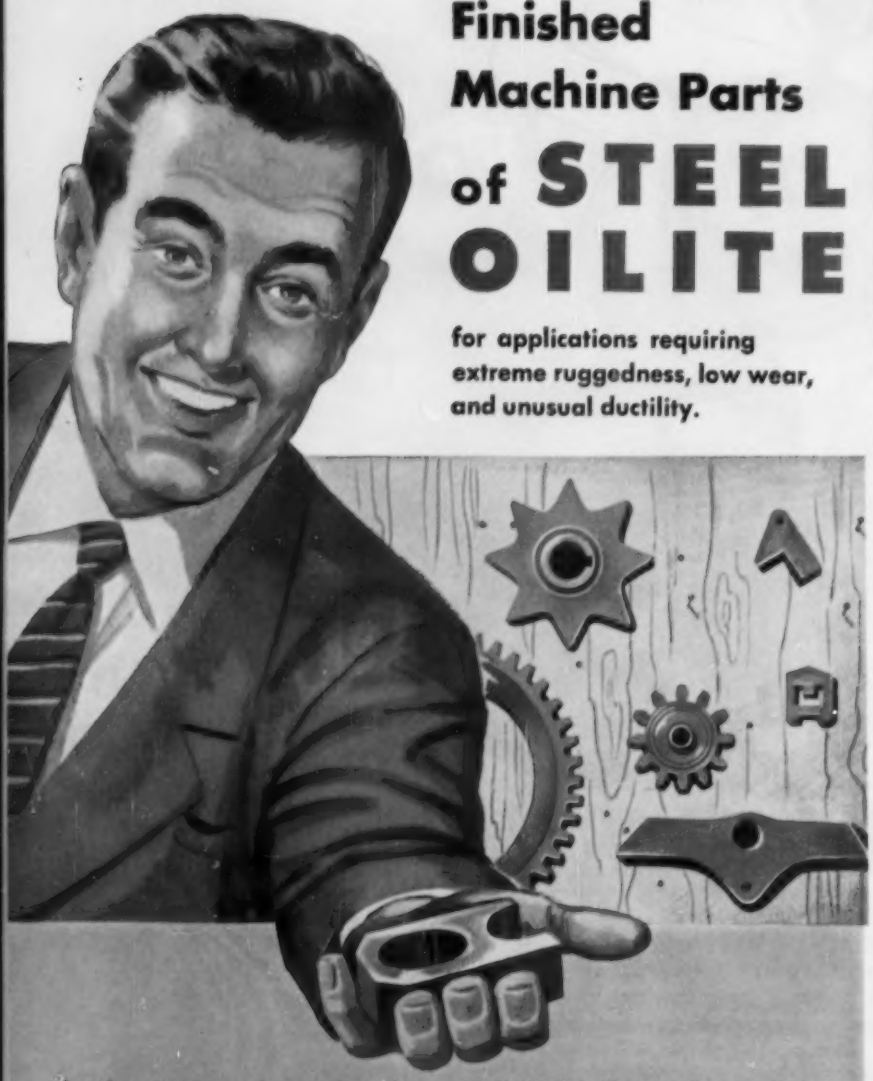

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Bainite Reaction . . .

rose from a range of Vickers 480 to 490 to Vickers 590 to 600. A completely convincing explanation could only have been based on photomicrographs, whose omission throughout the paper seems somewhat irregular in view of the subject matter.)

A group of 18 paired dilatometer and fatigue data had been obtained on steel 42 MnV 7 (aeronautical steel, analysis omitted). "Careful evaluation" of the dilation curves disclosed a relationship between fatigue life and homogeneity of structure and the author holds that somewhat inadequate cooling rates caused the great scattering of the results. The 18 bars were divided into two groups, one of which was austempered in an agitated salt bath and the other in a still bath. Full transformation to bainite should have resulted in a dilation of 400 units, the average for the still bath being only 359. All bars were loaded to 115,000 psi.

Without showing the individual data, the author states he (arbitrarily) divided them into groups using first 380 expansion units and then a million load reversals as the dividing line. He reports the average fatigue life of each expansion group and the average expansion of each fatigue life group. He also gives the average extension and average fatigue life of the specimens from each bath, but consistently omits the number of specimens in each group and the range of scatter (information which would have enabled a statistician to calculate the significance of the differences shown). Obviously, the extreme variations in fatigue life, characteristic for the region including life lengths of a million reversals and more, could easily cause one or two test results in a group of arbitrarily divided data, to bias the comparison between groups. Had the data really been able to support the conclusions, a simple rank correlation analysis would have revealed the probability of equivalence between an arrangement in the order of increasing deflection and an arrangement in the order of increasing fatigue life.

The section on martempering suffers from the same rambling presentation as the first section, but the data presented are of considerable interest and support the conclusions.

(Continued on p. 188)

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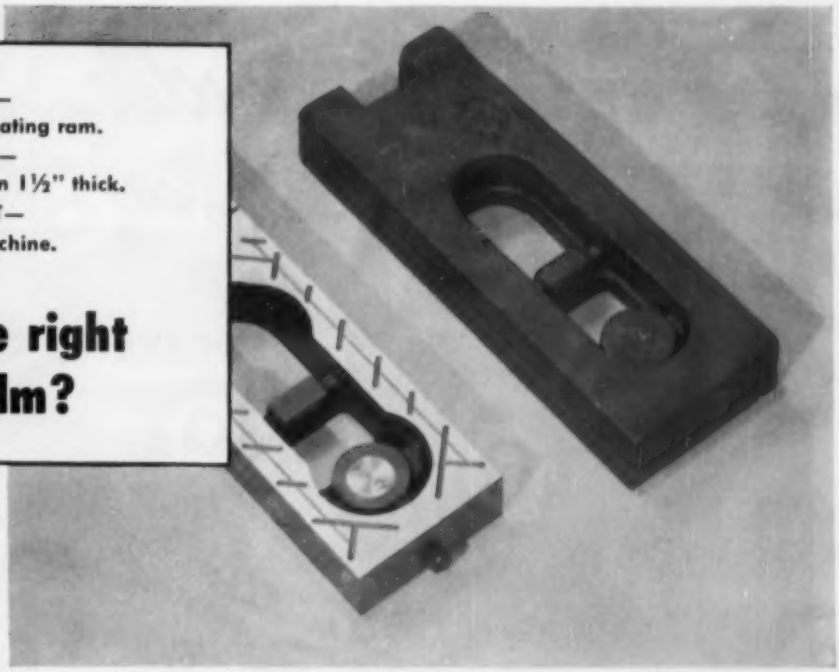
MATERIAL—
High-strength cast iron 1½" thick.
EQUIPMENT—
220 kv x-ray machine.

What's the right x-ray film?



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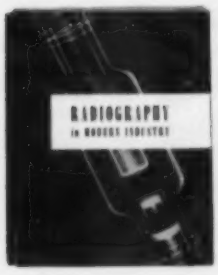

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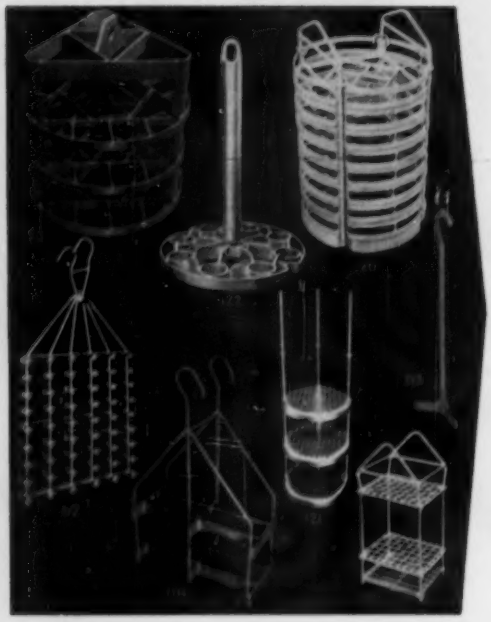

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Bainite Reaction . . .

The definition of martempering contained in the accepted German standard specification and the one proposed by leading American engineering societies agree in recommending a quenching bath temperature slightly above or in the upper region of martensite formation and in stating that martensite should form mainly during the cooling to room temperature. Ball-bearing and similar steels can be martempered accordingly, but the definition fails to hold for numerous other steels. The author quotes the Metals Handbook, p. 629*, as stating that a temperature of 400° F. is sufficient (for most purposes) for martempering a 0.40% C steel; the author then points out that the Ms for S.A.E. 5140 lies at 644° F. and for 99% martensite at 464° F. Several other examples are cited to show that "the German and American definitions of martempering do not hold for the bath temperatures recommended for these steels".

The inclusion of Ms and the temperatures of 50 and 99% martensite in isothermal diagrams is useful, but, unfortunately, has supplanted rather than supplemented the incubation times for the subsequent bainite reaction which formerly used to be shown. The common practice of martempering for 5 min. often results in a heterogeneous structure of martensite and bainite and, therefore, needs to be checked against these incubation times. Since published isothermal diagrams no longer contain this information, it should be obtained experimentally for each individual martempering process. The author shows that the formation of heterogeneous structures can be readily detected from data obtained with his rapid-action dilatometer, since a change in the mode of reaction results in unmistakable changes in the slope of the dilation curves.

Hollow cylinders, 2.362 in. long,

(Continued on p. 190)

*EDITOR'S NOTE — The statement referred to is: "A temperature of 400° F. is satisfactory for the martempering of many steels containing about 0.40% C. As discussed elsewhere in this Handbook (p. 611) the Ms temperature varies with carbon and alloy content and this influences the choice of temperatures for the quenching bath."

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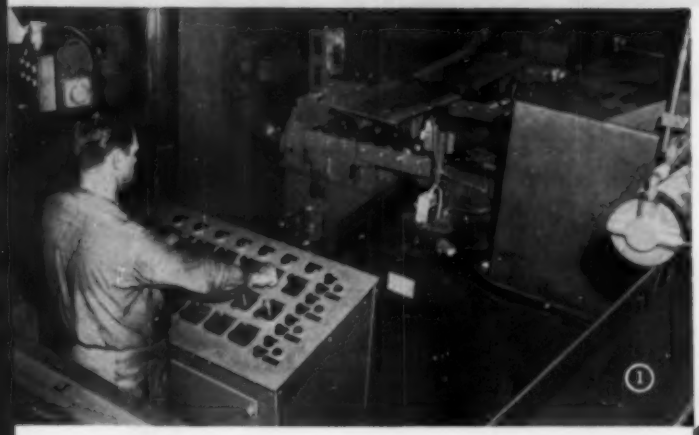

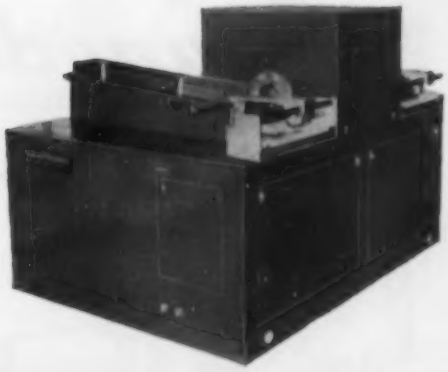

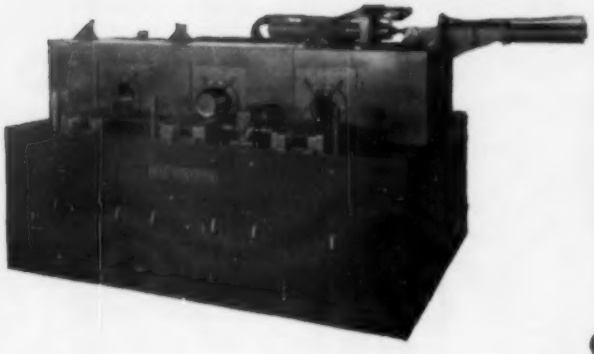

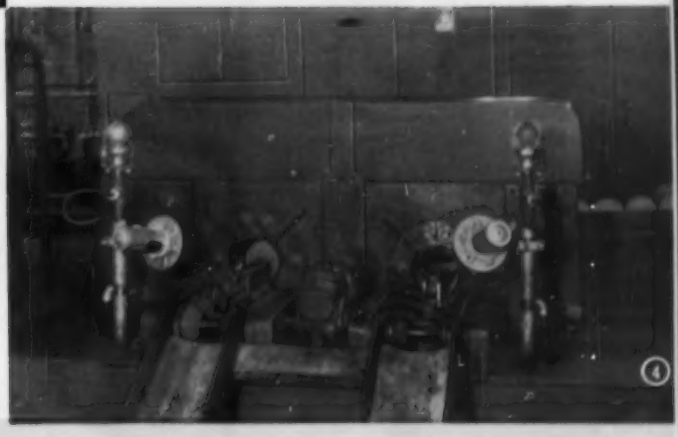

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Bainite Reaction . . .

with 0.394-in. I.D. and 0.079 to 0.118-in. wall thickness, made from a ball-bearing steel containing 0.89% C and 1.28% Cr, were austenitized at 1580° F. and transformed at 610, 480, 455 and 420° F. At the three highest temperatures, only bainite was formed, but a slight deviation in the curve at 455° indicated a change in the mode of transformation from an initial martensite to a subsequent bainite reaction. At 420° F., the two successive transformations could be separated into a martensite reaction completed in 5 min., followed by a bainite reaction which was incomplete after 3 hr.

A test piece austenitized at 1580° F. and transformed to bainite at 610° F. expanded 280 units. Two specimens, transformed, respectively, 3 and 7 min. at 355° F., then transformed in a bath at 610° F., expanded only 155 units at the higher temperature. (Correction was made for the expansion on reheating to 610° F.) The author concedes certain inaccuracies to affect such experiments, but concludes that about 55% bainite remained to transform at 610° F., 45% having transformed to martensite in 3 to 7 min. at 355° F.

Another specimen was put through a cycle consisting of 3 min. at 610° F., 3 min. at 355° F. and completion of transformation at 610° F. The expansions were, respectively, 153, 14 and 119 units, or a total of 286, compared to 280 for uninterrupted transformation at 610° F.

These data indicate that 55% austenite transformed to bainite during the first 3 min. at 610° F., 5% during the succeeding 3 min. at 355° F., and 45% of the austenite transformed to martensite in 3 min. at 355° F., when specimens were quenched directly into a bath of that temperature. The author suggests that this evidence might mean that bainite and martensite form from the same nuclei, an opinion which has been expressed by Krainer and Kroneis in *Archiv für das Eisenhüttenwesen*, Vol. 22, 1951, p. 242.

The evidence of an initial, rapid reaction followed by a slow transformation, observed at 420, 455 and 315° F., seemed to indicate that the martensite reaction was not instantaneous but progressed with time.

(Continued on p. 192)

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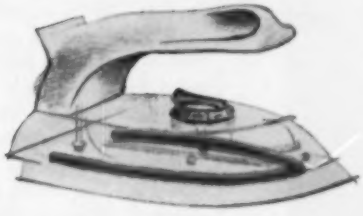

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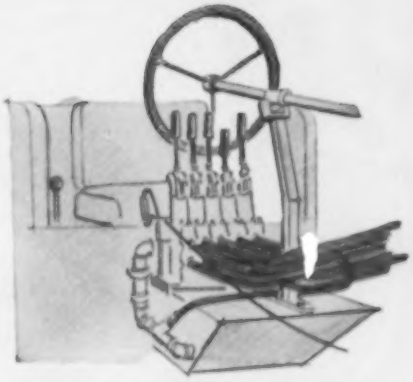

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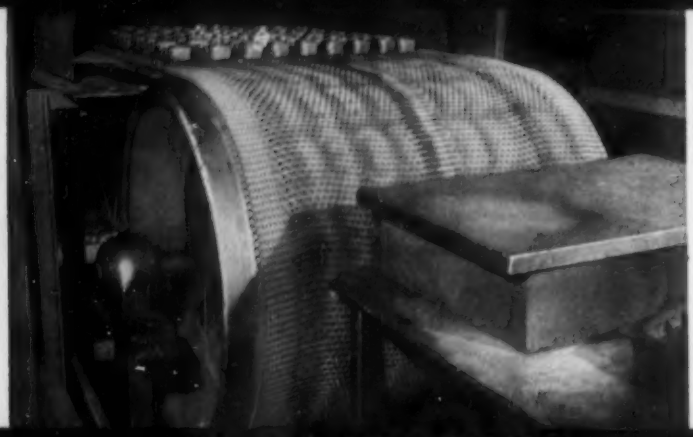

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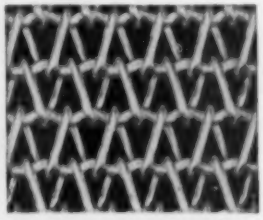

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Bainite Reaction . . .

Further evidence was obtained by transforming specimens at 285 and 220° F. To accelerate the cooling, the specimens were immersed for a few seconds in warm salt water before immersion in the transformation bath, so that they reached bath temperature in 20 to 30 sec. A few seconds after temperature equilibrium had been reached, expansion commenced and continued for about 100 sec. at 220° F. At both temperatures, the ogive-shaped curves were typical of isothermal reactions.

A test piece from another heat of ball-bearing steel, when quenched in oil at 230° F., contracted for 30 sec. until it reached the temperature of the bath but began to expand after 40 sec. (10 sec. at 230° F.) and continued expanding for over 10 min. Somewhat hesitatingly, the author suggests that this evidence indicates martensite transformation may be dependent upon time. This conclusion would seem rather inevitable on the basis of the apparently reliable dilatometric evidence.

REVIEWER'S COMMENTS — The article is written in an extremely rambling style, numerous experiments being described in detail, step by step, paragraph after paragraph. The manner of presenting the information is so tedious that very few readers could want to follow and retain the maze of detail to the extent required to see the entire perspective of the work and judge how well the experiments support the conclusions made by the author.

Some of the information which had been scattered through several paragraphs, in various ways, had to be tabulated before I could determine what it added up to. I felt that the section on austempering certainly contained some valuable material, but was carelessly presented and did not support the broad conclusions drawn. The arbitrary way some of the data are analyzed deserves notice and criticism.

The section on martempering is better. It contains some very interesting experimental results, but this too is poorly presented. Not only does this reviewer conclude that the author must have been pressed for time, but that the editor should have called for a revision.

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Fusion Welding of Titanium*

THE WORK described in this report is particularly useful since it includes not only the evaluation of the properties of flat butt welds but also the testing of several welded structures under simulated service conditions. The results show that satisfactory welds can be made in commercially pure titanium (RC-70 and Ti-75A).

Initial tests were made to determine the proper welding conditions and to evaluate the mechanical properties of the resultant welds. Mechanical and manual welds were made using a welding jig to locate the 0.063-in. sheet material. The welding conditions are summarized in the tabulation on page 196. The copper backing bar used on all welds of sheets was grooved ¼ in. wide and 0.010 in. deep, a conformation which preliminary tests had indicated most satisfactory. The mechanical properties of these welds were evaluated by tensile, bend and fatigue tests. The tensile tests gave essentially identical results, with failure occurring in the base metal at approximately 75,000 psi. ultimate strength and 17% elongation. The results of the 180° free-bend tests in general corresponded with most values of bend diameter between 2 and 3 times the sheet thickness. Calculated local elongations for the bend tests were generally in the range of 20% to 30%. Fatigue tests of the unwelded, manually welded and machine welded specimens gave endurance limits of 46,500, 39,000 and 43,900 psi., respectively.

To prove that production welding of titanium is practical, a number of welded assemblies were constructed and tested under simulated service conditions. These included a small spherical tank approximately 5 in. diameter, a 50-lb. thrust rocket and a corrugated sheet assembly.

Four spherical tanks were made, two being welded manually and two having mechanically made girth and boss welds. The assembly was accomplished by employing simple

(Continued on p. 196)

*Digest of "Fusion Welding of Commercially Pure Titanium", by Francis H. Stevenson, *Welding Research Supplement*, Vol. 19, March 1954, p. 1475-1535.

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"In not one single instance have we found an error in our Baldwin that has contributed to any erroneous tensile data. Error in this ordnance work must not exceed 1%. A recalibration of the machine after 8 months of operation showed a deviation of only ½ of 1% over the entire 60,000 lb. range . . . enabling us to double required tolerance!

"In view of such dependable performance we are looking forward to using our versatile Baldwin for other invaluable applications. The low-cost operation of the machine with its convenience and ease of handling makes it a natural for experimental testing. Testing of incoming metals for the purpose of eliminating wastage and downtime plus testing welds of all types are only two of the applications we now have in mind."

Nesco concludes, "Since being installed by Baldwin's engineers in ready-to-use form, this machine has given us complete trouble-free service."

You, too, will benefit by using this low priced, versatile testing machine . . . for many diverse applications. For complete information, write now to Dept. 2624, Baldwin-Lima-Hamilton Corporation, Philadelphia 42, Pa.

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150	300	550	1100	1650
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175	325	650	1200	1750
188	338	700	1250	1800
200	350	750	1300	1850
213	363	800	1350	1900
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Welding Titanium . . .

jigs which not only held the parts in place but provided argon gas to the interior of the hemispheres to prevent contamination of the back of the welds. These welded tanks were proof-tested at a hydrostatic pressure of 1200 psi., followed by 30 min. at 900 psi. The pressure was then relieved and the tank repressurized at a rate of 50 psi. per min. until failure occurred. Three of these tanks showed quite reproducible results, the final failure occurring at pressures of 2680 to 2760 psi. In welding the fourth tank, the shielding of the boss weld was inadequate and this joint was rewelded prior to testing. This tank failed at 1060 psi. in the rewelded area. Further evaluation of repair welding was done on flat sheet wherein rewelds were made over the entire length of an existing weld. These rewelds had

(Continued on p. 198)

Welding Data for 0.063-In. Ti-75 A Titanium Sheet

Welding Data	Specimen Number					
	1	2	3	4	5	6 to 9
Filler wire	Ti-75 A	None	None	Ti-75 A	Ti-75 A	None
Wire diameter, in.	0.062	.....	.....	0.062	0.062	.....
Direct current, amp.	100	100	100	100	100	50
Arc voltage	.....	.....	.....	.....	.....	13
Inert gas	Argon	Argon	Argon	Argon	Argon	Helium
Torch, cu. ft. per hr.	30	30	30	25	25	25
Backing, cu. ft. per hr.	10	10	30	10	None	10
Method	M	A	A	M	M	A
Carriage speed, ft. per min.	.....	20	18	.....	.....	19

Notes: Straight polarity, thoriated tungsten electrodes (⅛ in. diameter) used in all tests; M is manual; A is automatic.

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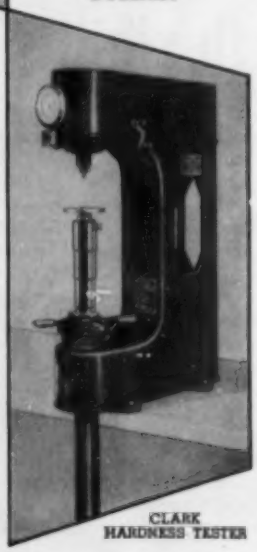

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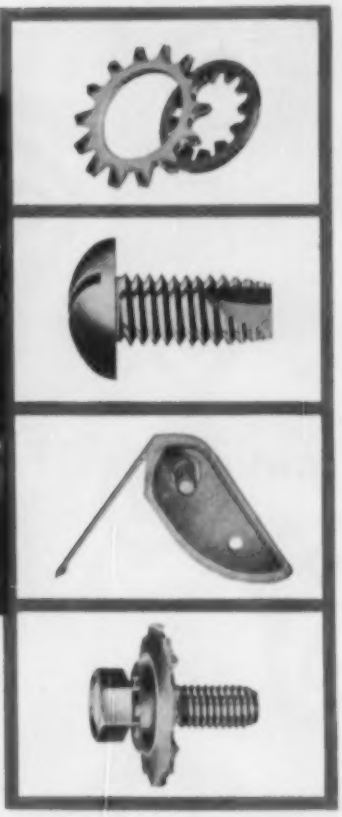

Heat-treating department at the Shakeproof Division of Illinois Tool Works, Elgin, Ill. A Nichrome muffle in one of these gas furnaces, operating at temperatures between 1500°F. and 1600°F., gave 36,732 hours of almost uninterrupted service between Sept., 1948 and April, 1954. Atmosphere consisted of ammonia and city gas.

In a rotary-type furnace in the same plant, a Nichrome retort operating at temperatures from 1600°F. to 1825°F., using ammonia and city gas, gave 17,248 hours of service.

36,732 Hours of Service From a NICHROME* Muffle

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For instance, they might easily have found a muffle with a lower initial cost than the Nichrome muffle they use in heat-treating their fastenings. But when you find that this muffle gave 36,732 hours of service over a period of 5½ years—the actual cost reveals Shakeproof as an intelligent buyer indeed.

Particularly so since a Nichrome retort in another of their gas furnaces, operating under somewhat higher temperatures and greater stresses, gave the same plant a total of 17,248 hours of service.

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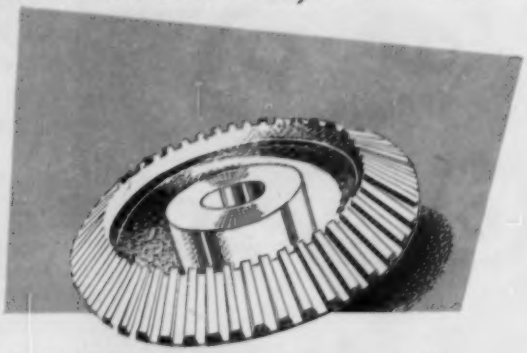
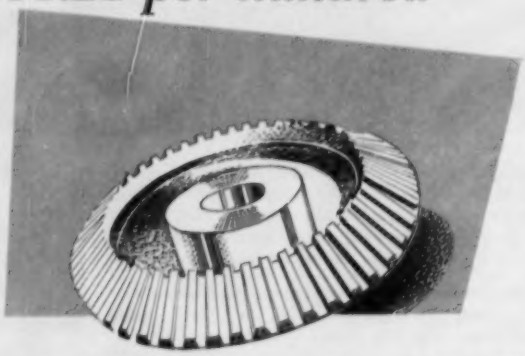


one costs $31.21 per hundred



and one costs $22.51 per hundred

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Tensile — 112,000 PSI	Tensile — 103,000 PSI
Elongation — 1%	Elongation — 2.5%
Rockwell Hardness — C34	Rockwell Hardness — B100
Apparent Density — 7.78	Apparent Density — 6.83
Production Steps — Nine	Production Steps — Four

**(7½% addition of 50% chrome/ 50% nickel, plus 1% carbon)*

Without obligation our technical sales staff will gladly give you complete information and show you how chromium-nickel pre-alloyed powders will meet your requirements. Write today!

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Welding Titanium . . .

good strength but tensile specimens developed a multitude of small cracks in the heat-affected zone. Satisfactory repair welds were made by grinding out the old weld and replacing it with new weld metal.

The 50-lb. thrust rocket was machined from commercially pure bar stock and assembled by welding. This motor was operated periodically for an accumulated time of 120 sec. Only a slight discoloration of the exit end occurred, whereas an identical motor fabricated from Type 347 stainless steel showed noticeable erosion.

The corrugated welded assemblies were constructed to check the effects of a number of welds made close together. The ends of the test section were closed by a plate to which pressure fittings were welded so that the tubular chambers could be pressurized either individually or collectively. Assemblies were constructed both with and without filler metal in the welds. Pressure tests on these assemblies showed failures at 1890 psi for the welds without filler metal and 2700 psi. for those with.

The author's conclusion is that fusion welds can be made using standard, inert-gas-shielded-arc welding equipment. The weld must be shielded carefully until it cools to approximately 400° F.; the number of welds coming together at any one point must be held to a minimum, and helium is preferred as a shielding gas when welds are made mechanically and argon when made manually.

D. R. LUSTER

Foundry College Sponsored in England*

AN INDICATION of the interest the English government and industry have in promoting sound foundry practices is the recent erection of a National Foundry College at Wolverhampton. The Government has provided the money for the site and buildings and the foundry industry contributed $21,000 in equipment and a similar amount in cash, the

(Continued on p. 200)

*Digest of "The National Foundry College", *Metallurgia*, Vol. 49, March 1954, p. 141.

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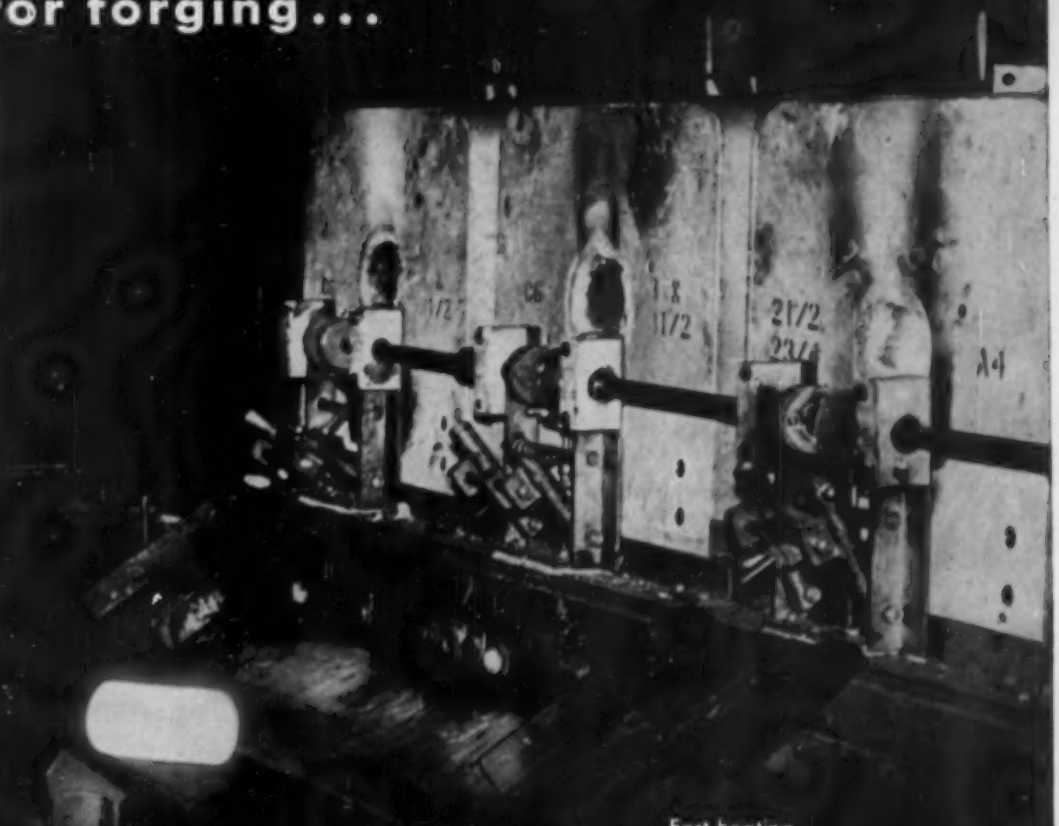

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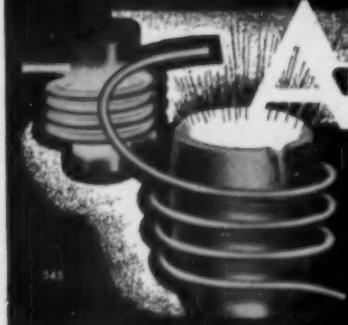

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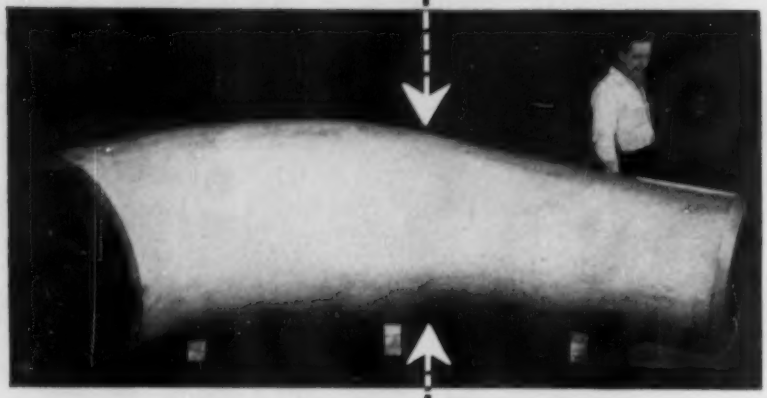

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Foundry College . . .

total investment amounting to about $420,000.

The college is well equipped with a variety of foundry equipment such as a number of electrical squeeze, snap-flask, pin-lift and turn-over molding machines, core-making machines with suitable ovens, a 12-in. cupola, two gas-fired furnaces of 200 lb. capacity having lift-out crucibles and a Sklenar gas-fired furnace of the tilting type. To be installed are a 15-lb. rocking-arc and a 30-lb. lift-coil furnace. There is also a centrifugal casting machine, a pressure die-casting machine and a Durville table. The usual cleaning, shot-blast, grinding and cut-off equipment is available. Very important, in this abstractor's viewpoint, is the 75-ton press for fracture tests on castings.

The ancillary facilities include X-ray, metallography, chemical analysis laboratories, and an adequately stocked library. One hopes that a high-frequency lift-coil furnace of 200 lb. capacity may soon be added to enable the students to study more efficiently the metal-mold reactions on a small but commercial scale. A dielectric core-drying outfit and the necessary shell molding equipment would undoubtedly be useful.

It is expected that much of benefit to the industry will be forthcoming from this Foundry College, to say nothing of an increasing number of practical foundrymen well trained in scientific fundamentals.

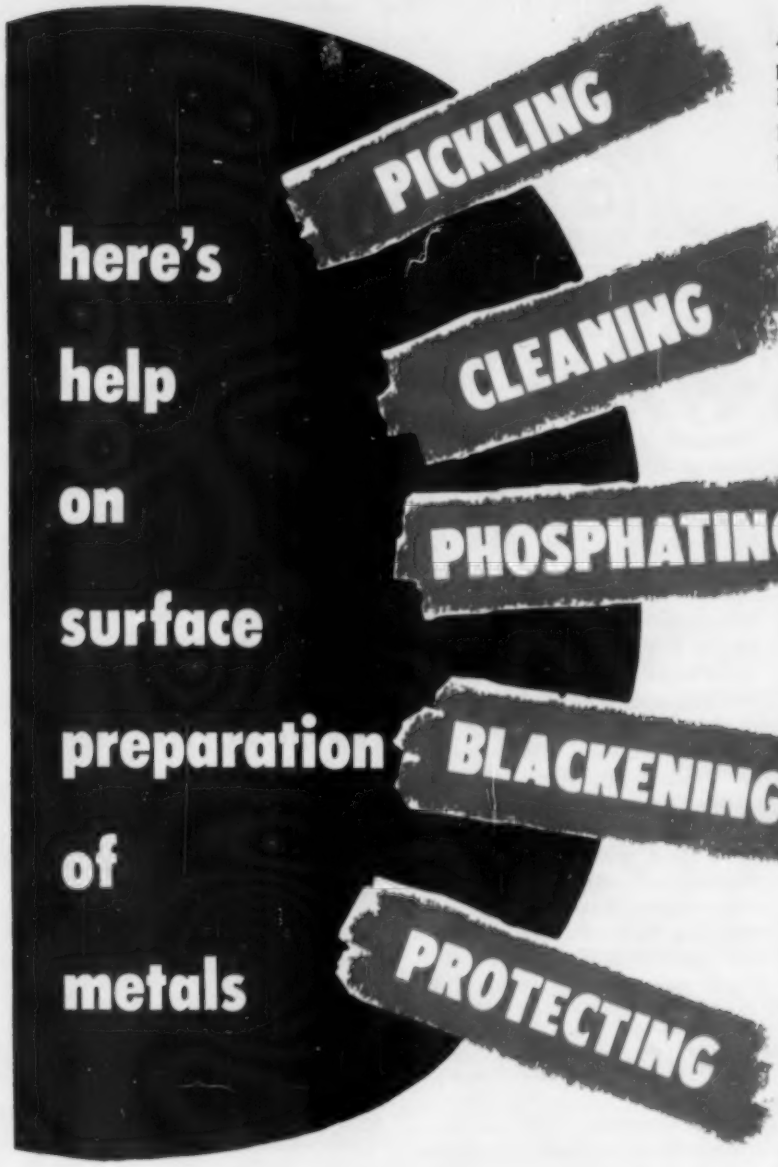
H. J. Roast

Brittle Welds . . .

(Starts on p. 114)

the responsibility of allowing vital parts to be welded from steels with brittle tendencies on condition that the joints be locally annealed. No complications whatever have arisen. Probably, no one can escape the thought that even a steel with brittle tendencies should be able to perform satisfactorily if the stress is reduced from 85,000 psi. to 15,000 or 20,000 psi., with a simultaneous improvement of the stress distribution, even though it might well have failed under minor service loads when added to the entirely unrelieved residual stresses.

(Continued on p. 202)



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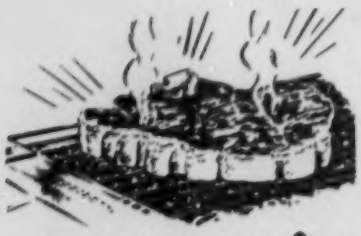

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Brittle Welds . . .

The author considers it necessary to advance this viewpoint again in preference to all other practical methods of insuring welded structures from brittle fracture.

One might, perhaps, object on the basis that riveted structures also contain residual stresses arising in the factory or during erection. Residual stresses are even necessary in joints held together by friction force. Ignoring the fact that the stiffness of riveted structures is less, the stress distribution at the joint is quite different. Around each rivet a local stress peak is surrounded by a corresponding valley. In the welded structures, on the other hand, the stress peaks extend with full intensity over the entire length of the joint.

Whenever defects arise in structural components, one should first attack the major cause; after that look to the minor ones. The essential cause of all brittle fractures in welded structures, according to the available experience, is assuredly to be found in the high level of welding stresses extending throughout the structure. Therefore, it seems essential to direct very special attention to correct techniques and measures before, during, and after welding which can reduce these residual stresses. Then only will the maximum degree of safety of welded structures be reached through correct design, safe material, and proper manufacturing methods.

French Steelmaking . . .

(Starts on p. 127)

The important theoretical results obtained so far are reported in a number of publications which have appeared simultaneously in English and French. We now are attempting to apply these results to industrial furnaces, and a number of similar projects are being carried out in the different participating countries. It is anticipated that this cooperative effort will bear much fruit.

In England BISRA (British Iron and Steel Research Assoc.) will continue research which began at the close of the War on furnaces fired by fuel oil or coke-oven gas, either on

(Continued on p. 204)

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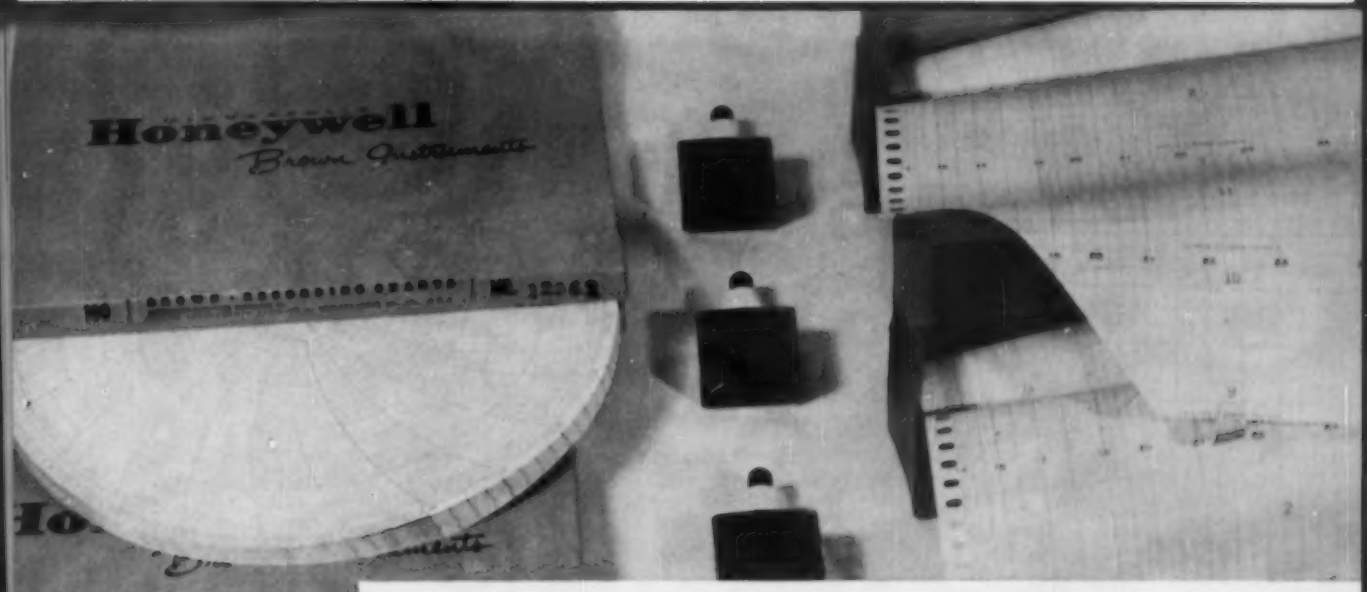

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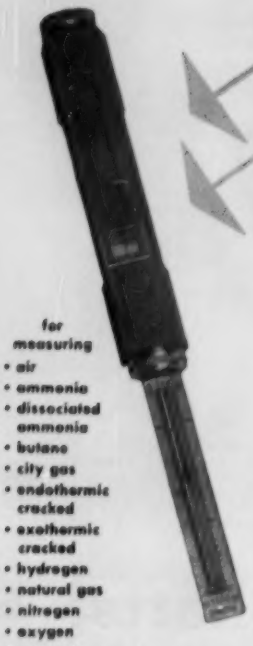

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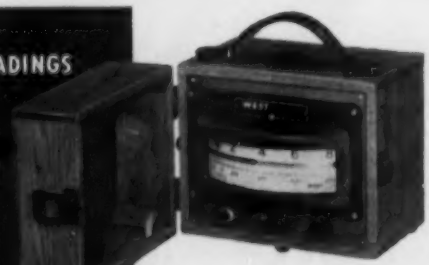

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French Steelmaking . . .

small models, experimental furnaces, or full-sized openhearths in steel plants. In France, IRSID will study furnaces fired by preheated mixed coke oven and blast furnace gas or producer gas.

A series of tests is in progress comparing efficiency of atomizing liquid fuels either by compressed air or steam. Results obtained at Ijmuiden showed that if this comparison is to be significant it should be based on equal movement of the atomizing agents – that is, for a given flow of oil, a larger volume of air should be used than steam according to their respective densities. Comparisons are not yet completed. In the meantime the French have not committed themselves to either method, though German practice favors air over steam, and steam is used almost exclusively in both Great Britain and America.

The above brief account summarizes what is new in the study of French steelmaking practices. Since we are not able to compete with North American volume of production, our research attempts to apply new techniques best adapted to the old continent. My remarks have been confined to the French aspects of European metallurgy, both because of the Editor's invitation and because I have wanted to speak from direct experience. We in France by no means underestimate the importance of the work done in the other countries of Western Europe – work which I described in its broad aspects a year ago for the readers of *Metal Progress*. In that review was mentioned the remarkable work carried out in Great Britain since 1945 on the combustion problems and heat transfer in Martin openhearths. Investigations on this same problem are also being carried out by P. de Graaf at the Royal Dutch steel plant.

Methods of making Thomas steel with low metalloid contents continue to be improved in Belgium, Luxembourg and Germany. Centralized mass production of oxygen is increasing in the steel works throughout Western Europe. Finally the Austrian process at Linz-Donawitz of refining by blowing straight oxygen from above in a solid bottom converter has stirred up much interest in America.

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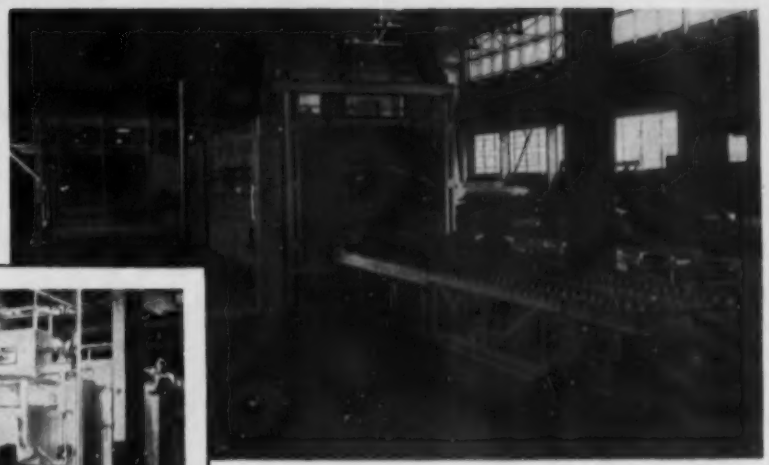

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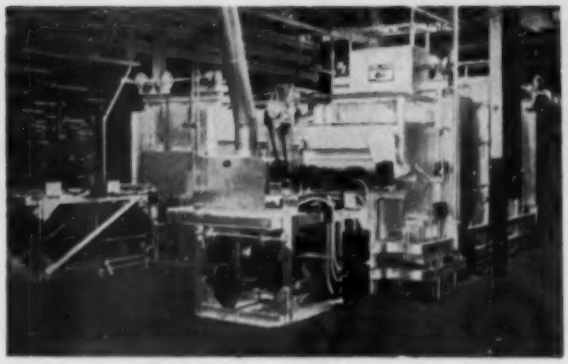

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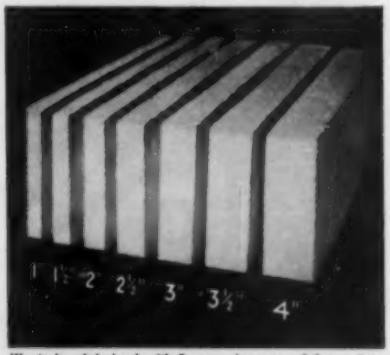

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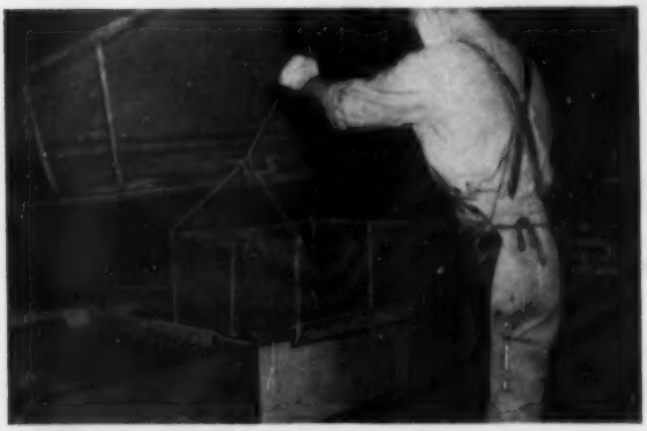

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Authors . . .

Tom Bishop

Sheffield-born, Tom Bishop received a metallurgical degree from his home-town university. He served in the British Army from 1939 to mid-1946, being among those who survived the ill-fated expedition to Norway. He became captain in the Royal Electrical and Mechanical Engineers, serving also in Iceland and Germany. He specialized in radar work, and tank armor development. He was a member of CIOS and BIOS teams which investigated German metallurgical works immediately after their surrender. After the war, he joined Industrial Newspapers, Ltd. (London), and is now editor of *Metal Treatment and Drop Forging* and metallurgical editor of *Iron and Coal Trades Review*. He is an associate of the Institution of Metallurgists, and a member of the Iron and Steel Institute, Society of Chemical Industry, and Institute of British Foundrymen.

A. L. Simmons

After graduating from University of Melbourne with a degree in metallurgical engineering in 1935, Mr. Simmons spent two years in the copper industry as research metallurgist for Electrolytic Refining & Smelting Co., Port Kembla, N.S.W. Since then he has been in the Australian Government service, first as metallurgist at the Munitions Supply Laboratories, then with the Government Small Arms Factories, and the Government Ammunition Factory, where he did considerable research on copper alloys. Since 1951 he has been engaged in planning work at the Head Office of the Government Munitions Organization, mainly on materials supply problems; official title: assistant director (materials), Defence Production Planning Branch, Department of Defence Production.

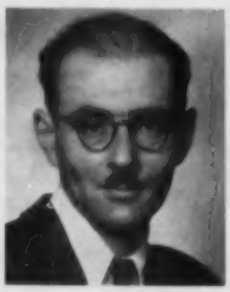
Walter Soete

Dr. Soete was born at Blankenberge, Belgium, graduated as a Civil Engineer at the University of Ghent in 1934, and later received the degree of Welding Engineer from the Ecole Superieure de la Soudure in Paris. He has been for many years scientific advisor of the Belgian Welding Institute and is vice-chairman of the Committee on Residual Stresses of the International Welding Institute. At the close of the war he became a faculty member at the University of Ghent.

Erik Rudberg

Dr. Rudberg is eminently fitted to discuss developments in physical metallurgy not only by his position as director of the important Swedish Institute for Metal Research, but also by his background as a physicist, lecturer and professor of physics at University of Gottingen, Sweden; King's College, London University; and Massachusetts Institute of Technology, where he was assistant professor of physics from 1932 to 1936. Returning to Sweden, he worked as a research physicist with the Swedish General Electric Co. until 1940, when he again became a professor at the Chalmers Institute of Technology, Gothenburg. He assumed his present position in 1945.

N. H. Polakowski



A graduate Mechanical Engineer (1938) from the Polish University of Lwow, Mr. Polakowski worked until 1945 in his native country as production engineer and departmental manager in tube mills except for the 1940-1941 period when he was employed by the distribution bureau of the People's Commissariat of Ferrous Metallurgy, U.S.S.R. This gave him

"an unusual opportunity to see and read things which normally are not widely known"—to quote his words. With the aid of the British Iron and Steel Institute he emigrated to England in 1948, and joined the metallurgical staff of the University College in Swansea. About a year ago, he came to the United States and is now consulting engineer for LaSalle Steel Co. and a lecturer in the department of metallurgical engineering at Illinois Institute of Technology.

Egon Kauhausen

H. A. Vogels

Mr. Kauhausen's doctorate thesis submitted to the ferrous metallurgy department of the Aachen Technical College in 1941 was on "The Weldable Hard Alloys of the Stellite Family". On graduation he joined the research department of Bohler Bros. & Co., becoming director of welding research, and is now acting chief of electrode production.

Mr. Vogels, like Dr. Kauhausen, is also a graduate of the metallurgy department at Aachen. For the last five years he has been with Bohler Bros. & Co.'s research laboratory (now assistant director) specializing in heat resistant alloys.

S. D. Heron

S. D. Heron began work on aircraft engines in 1909 as a machinist in England. In 1913 he started on air-cooled cylinder design work and began cylinder research and development in 1917. In 1921 Heron came to the United States and joined the U.S. Army Air Corps at McCook Field, Dayton, Ohio, as engineer on air-cooled engine design and development. He was with the Wright Aeronautical Corp. in the years 1926-1927 and then returned to the Air Corps at Wright Field. While at Wright Field he was engaged in engine research and development and undertook an extensive study of aviation fuels. In 1934 he joined the Ethyl Corp. and was in charge of aviation fuel development. Since 1946 he has been a consulting engineer and is co-author of a book on aircraft engines and fuels (reviewed in *Metal Progress*, September 1954, p. 96).

Jacques Pomey

Jacques Pomey, Laureate of the Academy of Sciences, has devoted his entire career to scientific research. Educated in civil and mining engineering, he has served with the Coal Mining Test Station at the Pompey Blast Furnaces of the Firminy Steelworks. He joined the Renault organization in 1933, becoming chief metallurgist, director of laboratories and (since 1952) scientific director of the Central Laboratories.

He is a professor at the Ecole Nationale Superieure de l'Armement and the Institut Superieur des Materiaux. He is past president of the Spectrographic Society, and the Stress Analysis Society, and past vice-president of the French Society for Metallurgy.

Gabriel Husson

Born in 1894 in the southeastern part of France, at St-Etienne, he received his metallurgical training in the School of Mines of his birthplace. For 18 years he worked first as an assistant and later as head of the openhearth shops of steel plants in central France. He spent the years of World War II and immediately after in different tasks connected with the steel industry. In 1947 IRSID, the French Iron and Steel Cooperative Research Institute, was formed and he was appointed as head of the steelmaking department, a position he still occupies. He received the War Cross during World War I and is a Knight of the Legion of Honor. *(More Authors' Biographies on p. 212)*

B. Fullman

E. C. Mantle

B. Fullman is a graduate in chemistry from the University of London. After a period as a university lecturer and some experience in technical journalism, he has spent the major part of his years in his present capacity, as chief information officer of the British Non-ferrous Metals Research Association.

E. C. Mantle is a graduate in chemistry with a Master of Science degree from the University of London, which he obtained by part-time study while taking a works chemist apprenticeship course at the British Thomson-Houston Co. at Rugby. Upon completion of his apprenticeship he was employed in the lamp works of the company as a powder metallurgist. In 1946 he joined the liaison department of the British Non-Ferrous Metals Research Association, and was appointed chief liaison officer in 1953.

Edouard Houdremont

Edouard Houdremont, a native of Luxembourg, studied metallurgy at Berlin Technical University from 1916 to 1921. He entered the Krupp works in 1926, and in 1931 was made head of the department of metallurgy and research. In 1939 he became a deputy member of the board of directors, and was a full member from 1943 to 1945. He heads the Werkstoffausschuss (special committee dealing with the quality of steel) of Verein Deutscher Eisenhüttenleute, and acts as a scientific consultant to Max-Planck-Institut für Eisenforschung at Düsseldorf. He holds the Carl Lueg-Gedenkmunze, the highest award accorded by V.D.E., and is the author of about 75 scientific papers dealing with metallurgy, as well as the author of "Handbuch der Sonderstahlkunde" (Handbook on Special Steel), the third edition of which will appear early in 1955.

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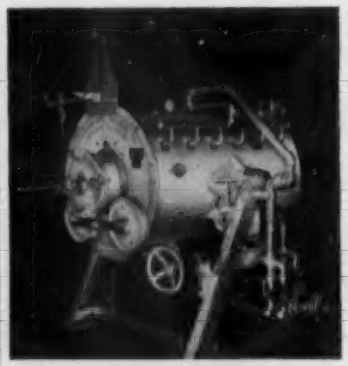

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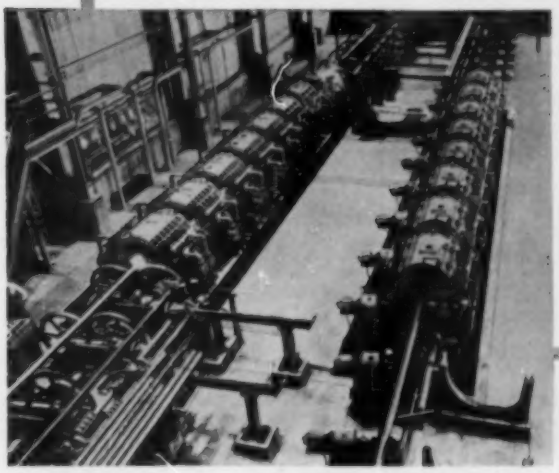

How Short-Cycle Tempering Improves Physical Properties

In general, heat treatment of steel (hardening and tempering) is designed to develop a proper relationship between strength and toughness. The primary purpose of tempering is to develop the desired plasticity or toughness, through relief of the residual hardening stresses.

Thermal stress-relief in tempering is achieved by a relatively greater reduction in yield strength as compared with the modulus, and by relaxation, or creep, which is related to soaking time. Thus, residual stresses in excess of the lowered yield strength initiate plastic flow and are thereby reduced. Also, creep accounts for plastic flow at stresses well below the yield strength, causing a further reduction in residual stresses.

By the nature of these reactions, tempering at a higher temperature is more effective in the relief of residual stress than a much greater time at a lower temperature used in conventional practise.

Accompanying these reactions is a second effect produced by the tempering heat, namely: coalescence of the carbides, resulting in a microstructure of greater plasticity. The added softening—and toughening—from this reaction is accompanied by decreased tensile strength.

Conventional heating cycles for tempering extend soaking time at lower temperature. In meeting the specified yield strength, tensile values are obtained which are higher than desirable for good machineability. On the other hand, tempering by rapid heating, with no soak, develops the required minimum tensile strength at a higher temperature. The high-temperature relief of residual stresses develops higher yield strength—for a given tensile strength—and higher percentage elongation, than steel tempered on long time, low temperature cycles.

The application of high speed gas heating for hardening and drawing of high strength steel tubing for the oil industry demonstrates that improved physical properties may be expected from short-cycle heat treating. The accompanying photograph shows a typical installation in the tube mill of a large steel producer. Tubes, up to 9⅝" diameter and 50 feet in length are conveyed with rotation through a series of barrel-type furnaces, supported on rolls between furnaces. After heating to a uniform temperature of 1650°F in less than 4 minutes, the tubing passes through an annular orifice-type water quench for hardening. The tempering line of furnaces is synchronized with the hardening line in terms of speed and heat input to develop the tempering temperature.

The method has permitted the attainment of physical properties in carbon steel superior to those formerly produced by a normalize and draw treatment of alloy steels. In addition, yield strengths in excess of 110,000 psi, together with excellent ductility, are obtained for deep oil well applications.

Short-cycle treatment by gas heating has also been applied to steel bar stock where high yield strength and ductility are desired in the end-product. A manufacturer of stud bolting noted, for example, that in employing short-cycle heating for obtaining the required yield strength, the resulting tensile strength was less, compared with conventional heating methods. Threading costs, previously excessive, were thereby substantially reduced.

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Automatic Safety System for Hydrogen Lines*

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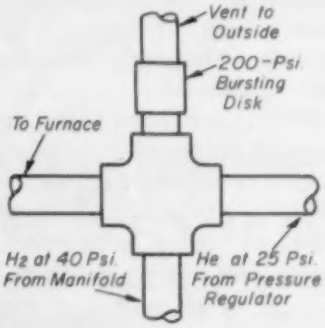
An automatic safety system was recently devised by R. M. Carson.



Helium is used to purge and flood the hydrogen lines. A cylinder of helium is connected in the hydrogen network. The pressure regulator in the helium line is normally set from 10 to 20 psi. lower than the hydrogen line (see sketch). The helium begins to flow only if the hydrogen-line pressure drops to that of the preset pressure of the helium. The hydrogen remaining in the system is then rapidly expelled until fully replaced by the safe helium.

This scheme is being used with complete success in hydrogen furnaces, radiant ovens and radio-frequency heating setups, and in various devices and components treated in hydrogen-filled enclosures.

*Digest of "Safety Installation for Hydrogen Distribution Lines", National Bureau of Standards' *Technical News Bulletin*, October 1954, p. 149.

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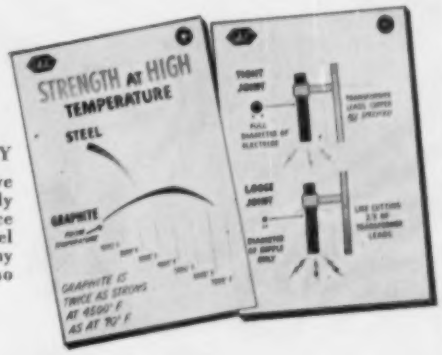

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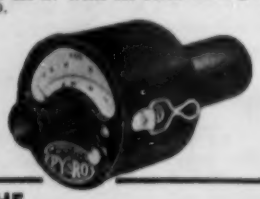

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Iron and Steelmaking in Sweden*

IT IS striking to note that iron and steel in Sweden are made by all of the known methods, acid bessemer, basic bessemer, acid openhearth, basic openhearth, acid and basic electric. In addition, large tonnages of high-purity sponge iron are made and the largest high-frequency melting furnaces in the world, handling 12 tons, are in operation in steel plants.

The unique feature of the Swedish situation is the presence of large tonnages of excellent iron ore (estimated at 3.2 billion tons) and a complete absence of mineral fuel for heat and combustion furnaces. Sweden thus exports iron ore and imports large tonnages of coke, coal, and fuel oil. In 1953, iron ore production was 18.8 million tons of which 16 million tons was exported and 2.8 million tons was consumed in Sweden. Since this ore averages 60% iron, 1.6 million tons of iron comes from the ore in making a total output of nearly 2 million tons of steel. There is always a shortage of steel scrap in Sweden because its finished steel production is also exported.

Fuel and Power – The lack of mineral fuel and world disturbances of fuel markets have always had a strong influence in Swedish steel practice. For years charcoal was the chief source of fuel and as late as 1930, 40% of the fuel used in the industry was charcoal. This has been reduced to about 8% in 1953 by factors such as higher labor cost of lumbering and making charcoal, competition by paper mills for wood, which raised the cost of wood, and cheap sources of electric power. In 1953, the ratio of fuels used was 10% charcoal, 50% imported coke, 15% imported raw coal, and 25% imported fuel oil. The latter is used entirely for firing openhearth, forging and heat treating furnaces.

This shortage of fuel led to the introduction of a variety of electric furnaces for both ore reduction and steel melting as long as 50 years ago. As electrical equipment has improved, the use of such furnaces has continually expanded until today fully one-third of the total energy consumed in the Swedish steel industry derives from hydroelectric power. In 1952 the power consumption per ton of steel amounted to 1970 kw-hr.

Pig iron is made in Sweden in charcoal, coke, electric high-shaft and electric low-shaft furnaces; about 10% use charcoal, 75% coke, and 15% electricity. The power consumption on electric blast furnaces averages 2200 kw-hr. per ton of pig iron and this cannot compete at present with the cost of coke smelting and is also more costly than the cost of sponge iron as made in the Wiberg-Soderfors process. At present about 165,000 tons of electric pig iron is produced.

All types of blast furnaces are charged with high-grade concentrated ore (65% iron) which is very low in gangue content. In later years the ore has been sintered or pelletized and fuel economies from these practices have been very good. Slag volume averages 500 lb. per ton and charcoal or coke consumption has been reduced over 25%. The Swedes prefer to use very high temperatures for sintering and pelletizing, aiming at a high content of Fe_2O_3 in the product. High hot blast temperatures such as 1645° F. are employed. As a result charcoal consumption of 1145 lb. per ton of pig iron and coke consumption of 1110 lb. are obtained.

Sponge Iron – There are two large-scale operations for making sponge iron in Sweden and production reaches about 55,000 tons per year. This product is used for the preparation of pure iron powders and for making special quality steels. The first method, introduced by Sieurin in 1911 at Hoganis, charges very rich concentrate (70% Fe) into ceramic muffles with coal or coke breeze as reducing agents. The carbon monoxide gas generated is burned outside the muffles, thus generating most of the heat needed.

The other sponge iron process was developed by Wiberg at Soderfors in 1918. Three separate shaft furnaces are used in this method. The reduction of the ore charge is done in a shaft where a mixture of carbon monoxide and hydrogen gasses, heated to 1740° F., enters the bottom. The ore charge must be very low in gangue (70% Fe) and is pelletized before

(*Continued on p. 218*)

* Digest of "Iron and Steelmaking Processes Used in Sweden", by Sven Fornander, *Journal* of the Iron and Steel Institute, Vol. 177, May 1954, p. 1-11.

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This is an open hearth furnace, fired by natural gas, at the International Nickel Company. Here, during the initial step in the production of malleable nickel for processing into commercial forms, Gas is used because it economically produces temperatures around 2900°F. Later, Gas works as a production line tool, insuring the bright finish of the metal and softening it in a continuous annealing furnace for further processing. This flexibility, plus its cleanliness, economy, and dependability, makes Gas the satisfactory method of heat processing. That's reason enough for discussing your problem with your Gas Company's industrial specialist.

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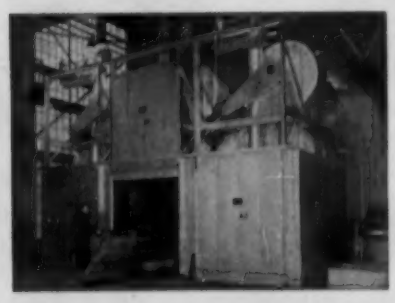

This battery of three aging ovens incorporates direct gas-fired recirculating air heating systems and other features which contribute to uniformity and faster, more economical production in a large aluminum company.

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Investigate the advantages and patented features offered in the heat treating furnaces and ovens designed and built by the Carl-Mayer Corp.—write for the new, illustrated folder today. Bul. HT-53.

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Iron and Steelmaking in Sweden . . .

charging to prevent bridging in the shaft. From a level about half-way up the shaft, where the burden has been reduced to FeO, most of the gas leaves the furnace and is led to a carburetor shaft. This shaft, heated electrically by two sets of electrodes, is filled with charcoal or coke. The carbon dioxide and water vapor from the reduction shaft are converted to CO and H_2 and then pass to a third shaft, known as a sulphur filter, which is filled with dolomite. The water gas is thus used over and over again. The product is discharged from the reduction shaft into closed containers to retard reoxidation and then carried to steel melting furnaces while still hot. This sponge iron contains about 90% Fe in metallic form together with the original gangue of the ore and a considerable amount of FeO. One of the great advantages of this operation is the production of iron of very low sulphur and phosphorus (0.005%). In addition only 420 lb. of coke and 950 kw-hr. are required for the production of 1 ton of sponge iron.

Steelmaking – Steel production in Sweden was 1,800,000 tons in 1953 and originated from the following methods:

Type of Furnace	Tons
Electric furnaces	890,000
Basic openhearth	490,000
Acid openhearth	220,000
Basic bessemer*	220,200
Acid bessemer	33,000

The acid bessemer plants are now mostly used to produce duplex blown metal for openhearth or electric furnaces. One plant with two 20-ton converters makes a low-nitrogen (under 0.008%) bessemer steel by blowing the vessel in a tilted position and then finishing with a large ore addition.

The basic bessemer plants are also largely used for duplexing although a considerable tonnage of commercial steels is made by this process. As in other parts of Europe, the Swedes have tried all of the new schemes for making low-nitrogen bessemer steel, such as blowing with oxygen-enriched air, blowing the last few minutes with mixtures of oxygen and carbon dioxide, and blowing with pure oxygen. One large oxygen blowing plant has been installed and the author states that the greater cost of this practice is justified by the large amounts of cheap scrap which can be melted. Interesting experiments have also been made to refine pig iron with pure oxygen in a rotary furnace. By this practice, very effective dephosphorization is obtained as well as extremely low nitrogen content; also, the dust problem is not so troublesome as in the oxygen-blown converter process.

Acid openhearth steel is made in small furnaces ranging from 20 to 55 tons capacity for special-purpose steels. Ball bearings made of acid openhearth steel have a considerably longer life than those made from electric steel. The charge used is high in pig iron with mixtures of sponge iron and steel scrap. The furnace lining is the purest form of silica. The high-carbon melts are heated during the refining period to a temperature where the carbon in the bath reduces the silica in the lining. This gives rise to a "silicon boil" which is controlled by observation of spoon samples. The silicon is oxidized, increasing the silica content of the slag to the saturation point. Slag composition remains almost constant from heat to heat.

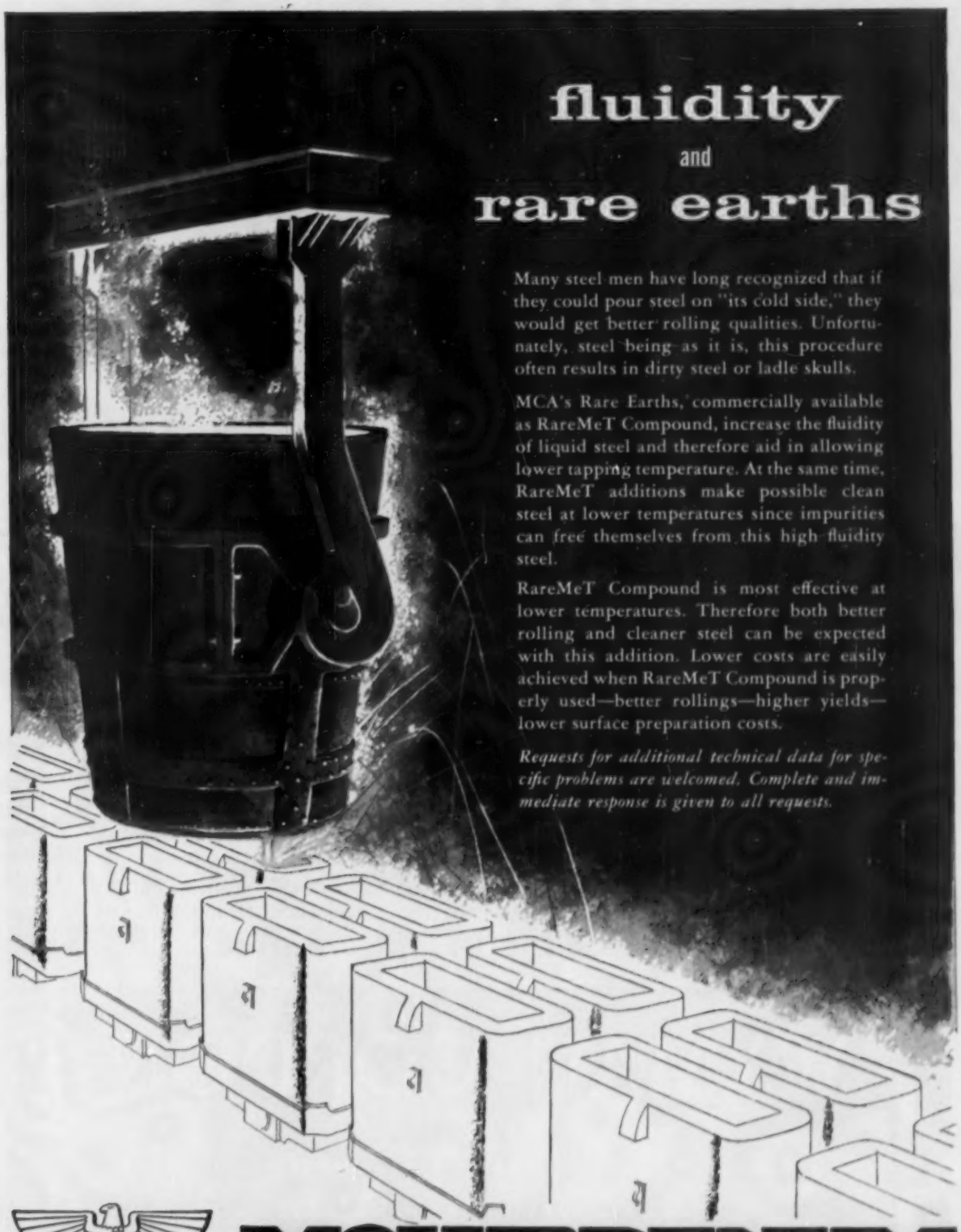
The basic openhearth is used mainly for making commercial steels. Furnaces are oil fired and average about 50 tons capacity.

Electric furnaces produce 46% of all steel and the output by this method has increased rapidly since 1945. Commercial steels are finished under an oxidizing slag while special quality steels are finished under a carbide slag and deoxidized in the furnace. Top charging is common and some of the newer furnaces have an electro-dynamic stirrer under the furnace bottom. Many electric furnaces are charged with blown metal entirely and special steels are made with this charge.

Any American steel engineer who is interested in developments in steel melting will be well rewarded in reading this concise and lucidly written paper. It is regretted that no economic comparison of the various processes is given.

E. C. Wright

*A new basic bessemer plant under construction will increase this capacity to 820,000 tons per year.



fluidity
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rare earths

Many steel men have long recognized that if they could pour steel on "its cold side," they would get better rolling qualities. Unfortunately, steel being as it is, this procedure often results in dirty steel or ladle skulls.

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RareMeT Compound is most effective at lower temperatures. Therefore both better rolling and cleaner steel can be expected with this addition. Lower costs are easily achieved when RareMeT Compound is properly used—better rollings—higher yields—lower surface preparation costs.

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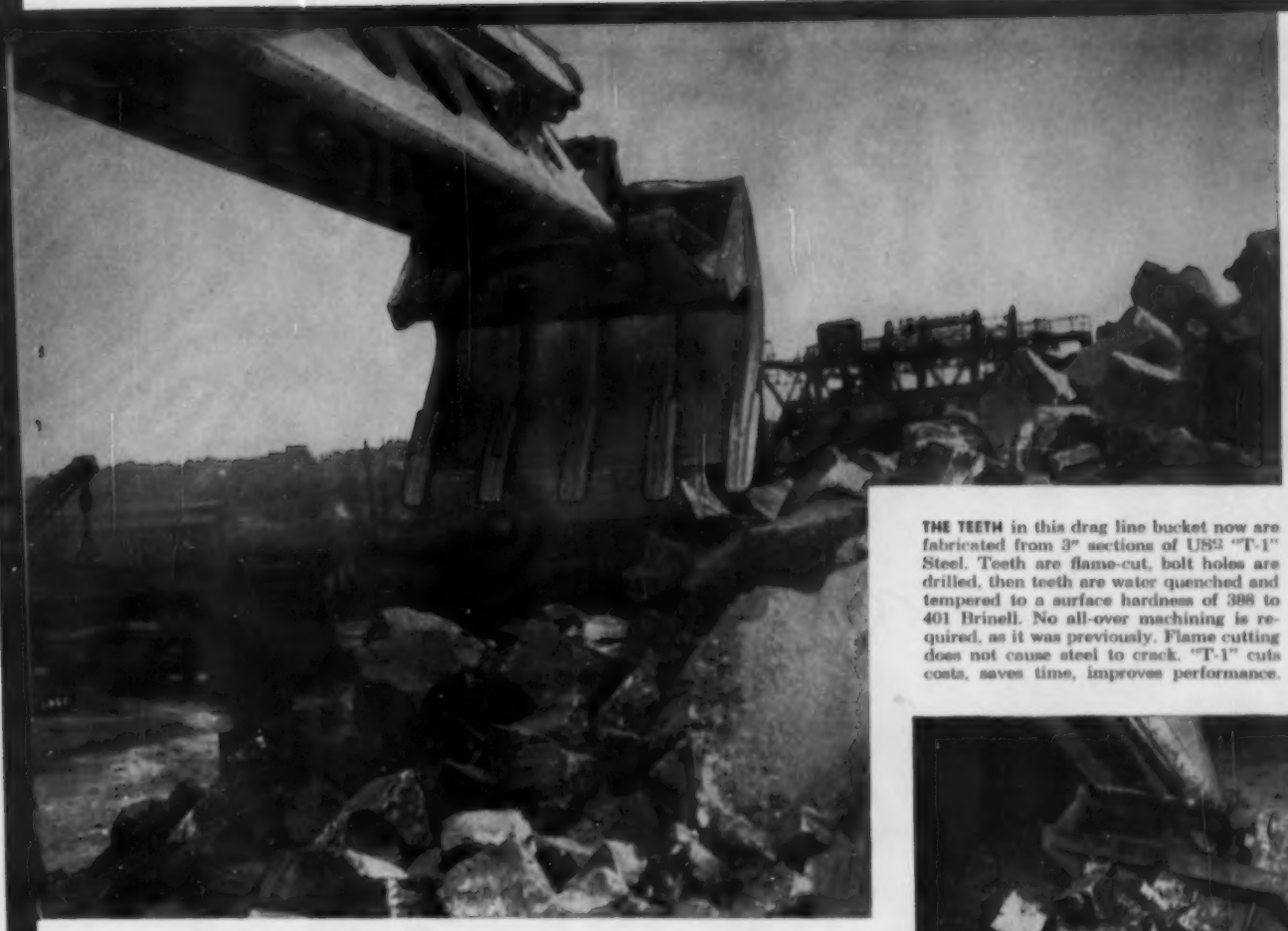

THE TEETH in this drag line bucket now are fabricated from 3" sections of USS "T-1" Steel. Teeth are flame-cut, bolt holes are drilled, then teeth are water quenched and tempered to a surface hardness of 388 to 401 Brinell. No all-over machining is required, as it was previously. Flame cutting does not cause steel to crack. "T-1" cuts costs, saves time, improves performance.

How USS "T-1" Steel in Drag Line Bucket Teeth increased service life ten times

This hefty drag line is used to break and load ferromanganese which is made by the Blast Furnace Department of U.S. Steel's Duquesne Works. Ferromanganese is extremely hard and dense, so the bucket teeth must have exceptional resistance to impact abuse and abrasion.

When we bought this machine, the manufacturer used the best steel then available for the job. But still the teeth broke easily – and lasted for only 4 to 8 hours of operation. Replacement down time was frequent and expensive.

Just as an experiment, we tried our new "T-1" Steel in this rugged application. It worked beautifully. Instead of 8 hours, we are getting *80 hours* of service from each set of teeth – ten times more. Down time and replacement costs are about *a tenth* of what they used to be. Naturally we'll continue to use "T-1" Steel in this job, in the entire bucket as well as the teeth.

USS "T-1" Steel can cut costs for you in a wide variety of applications. Write for detailed facts and figures.

USE "T-1" AT HIGH TEMPERATURES. New USS "T-1" Steel has good creep rupture strength up to 900° F. It is being used in heavy-duty parts that operate at high temperatures.

USE "T-1" AT LOW TEMPERATURES. This same steel is amazingly tough at sub-zero temperatures. In pressure vessels, it has survived impacts of 2,000,000 ft. lbs. at 38 degrees below zero F. In addition, it has good resistance to impact abrasion.

USE "T-1" TO CUT FABRICATING COSTS. You have a yield strength of 90,000 psi. in "T-1" yet you can weld or flame cut this steel without pre- or post-heating. Your welds will develop the full 90,000 psi. And you can fabricate parts either in the shop or the field—wherever it is more convenient and less costly. With "T-1" Steel you can save money or improve design—sometimes both—in bridges, pressure vessels, heavy-duty trucks, excavating machines, mine cars, high speed rotating machines, steel mill equipment, and stamping and forging presses.

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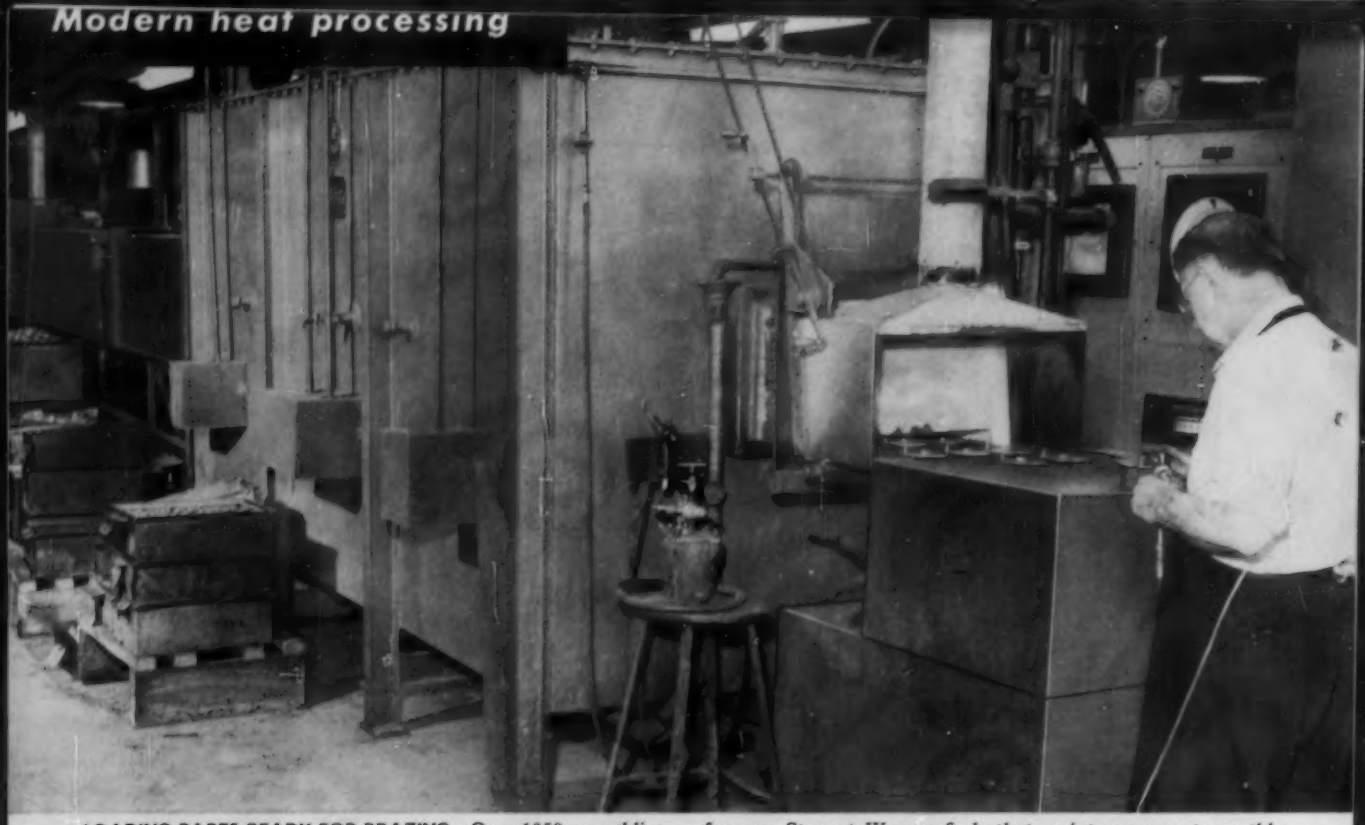
USS "T-1" CONSTRUCTIONAL ALLOY STEEL

USS

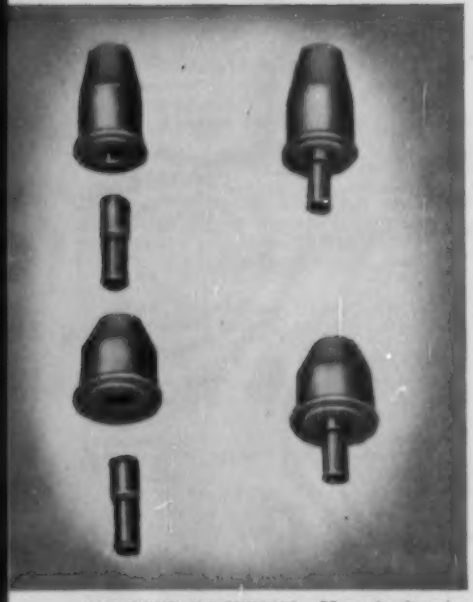
5-203

UNITED STATES STEEL

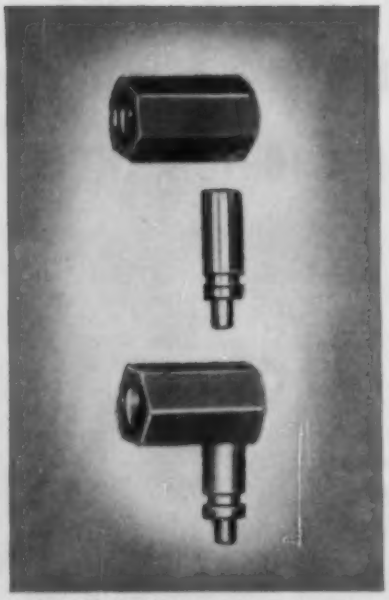


LOADING PARTS READY FOR BRAZING—Over 1350 assemblies per hour can be brazed by one man with this G-E mesh-belt furnace. Stewart-Warner finds that maintenance costs on this furnace are even lower than estimated at the time of purchase.

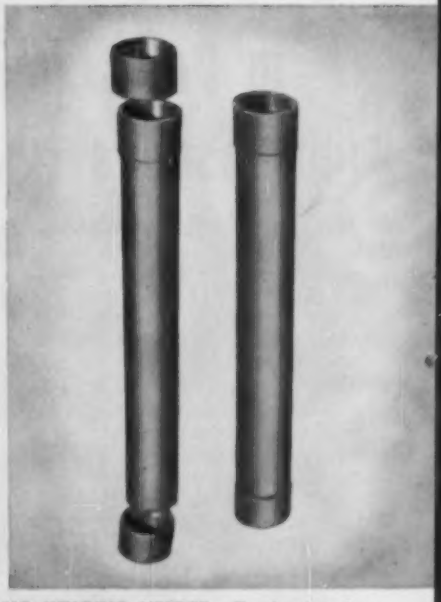
Stewart-Warner Speeds up Production



NO HAND MACHINING—Now the ferrule bodies are screw-machine parts and the extensions are made on a punch press.

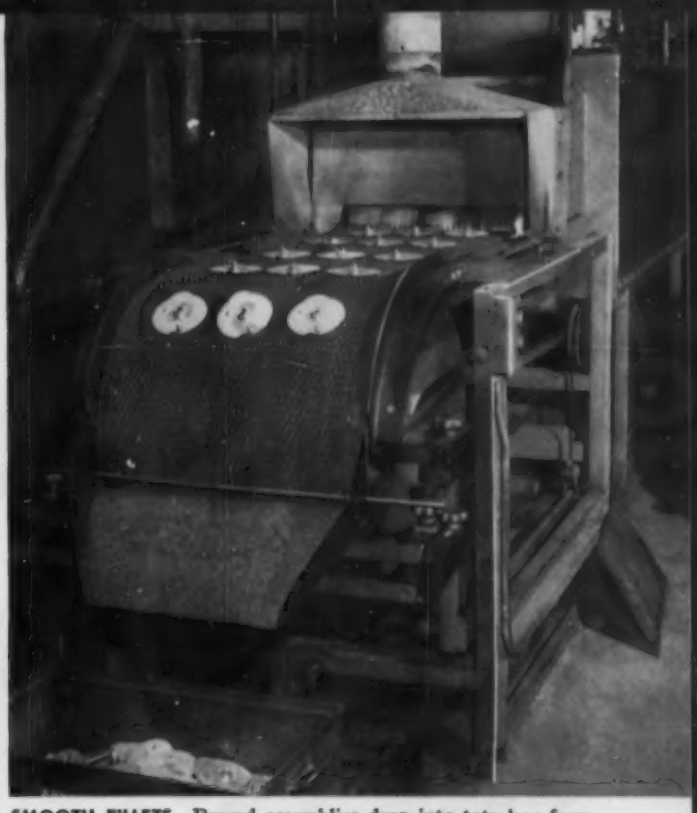


NO FORGING NEEDED—Now the components of this elbow (top) are made by screw machines and furnace brazed.



NO WELDING NEEDED—Production has been speeded by brazing rather than welding this cylinder assembly.

ONE OPERATOR BRAZES MANY PARTS—Copper brazing paste is applied as operator places assemblies on mesh-belt.



SMOOTH FILLETS—Brazed assemblies drop into tote box from G-E furnace clean and bright with smooth fillets at joints.

by Brazing in General Electric Furnace

Reduces Rejects and Lowers Costs By Eliminating Expensive Operations

Assembly rejects practically eliminated, material costs reduced, by brazing with a General Electric mesh-belt furnace, reports a large Chicago manufacturer of lubrication-system and automotive parts.

Says Henry Orth, General Foreman and Metallurgist of the Stewart-Warner Corporation: "By brazing assemblies in a G-E furnace instead of welding them or machining the complete part from a single piece of stock, production per man hour has been boosted considerably. We've also been able to simplify the design of many parts. The over-all result: substantial savings in labor, handling, and material."

G-E FURNACE ELIMINATES 3 OPERATIONS

Machining—With furnace brazing, parts that formerly had to be machined in one piece can now be broken down into simple components for quick production at low cost on screw machines or punch presses.

Forging and Welding—Parts formerly welded, or forged and welded, are now electric-furnace brazed with less labor. One unskilled operator can braze several times the quantity that could be welded by one man. After brazing, the parts are clean and bright with smooth joints. No machining is required.

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Stewart-Warner's experience is another example of the benefits of modern metal processing with electric furnaces. To improve your operation, look to General Electric, a pioneer in the development of better industrial heating equipment. G-E service facilities are unmatched by any other heating equipment manufacturer. For application help from a G-E Heating Specialist, contact your G-E Apparatus Sales Office.

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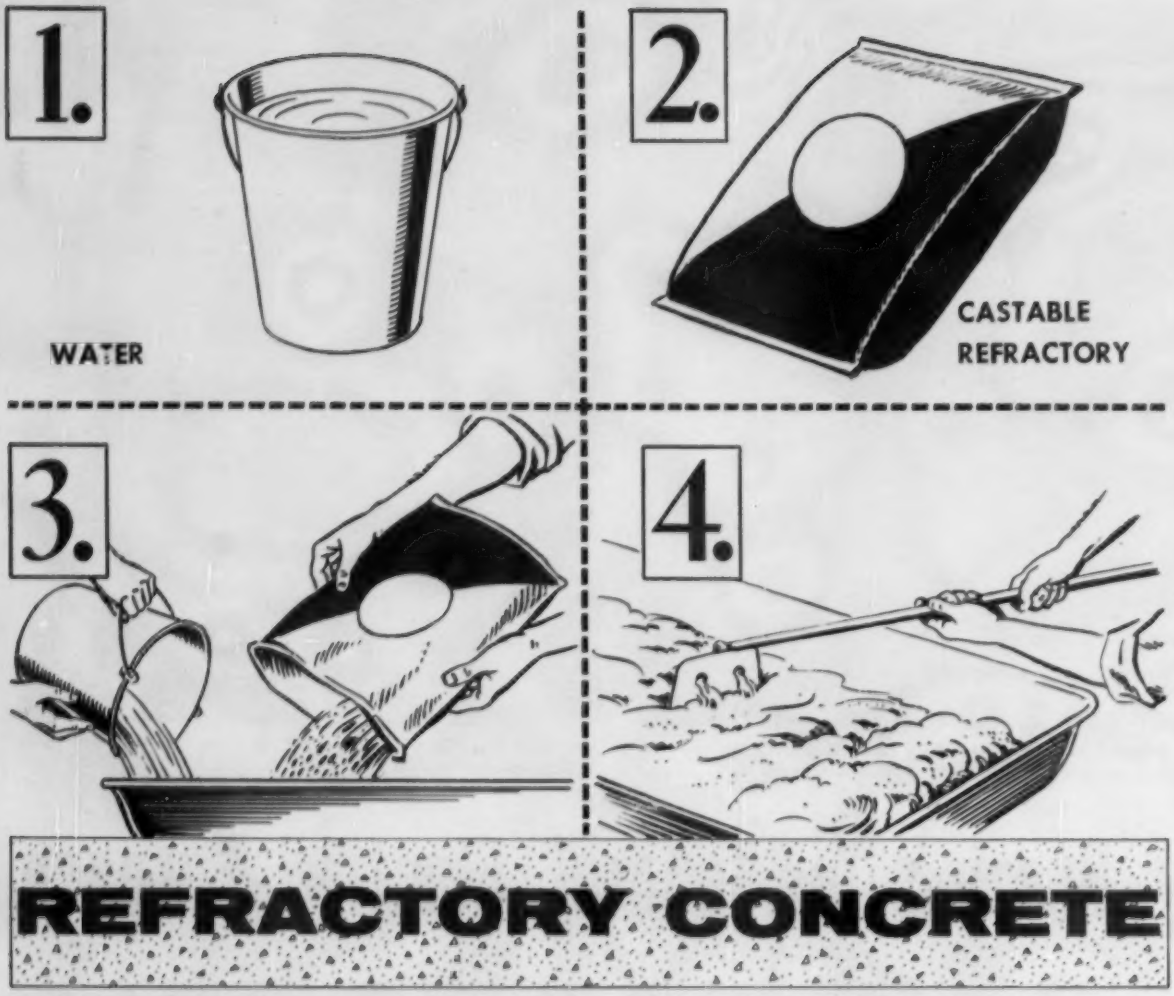

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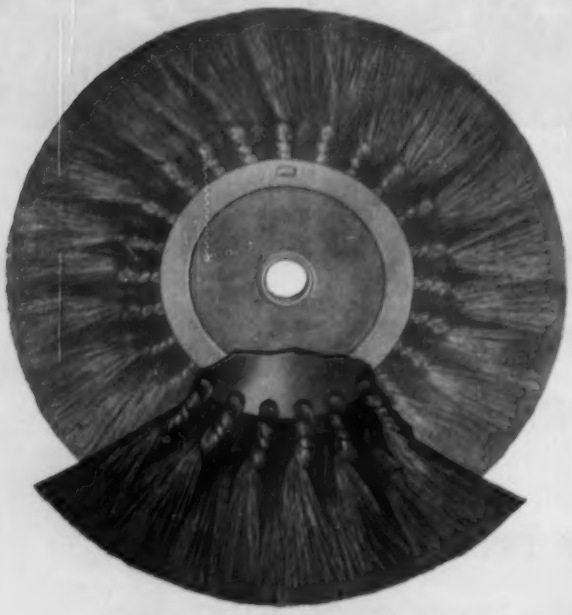

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By C. Preston Critzer

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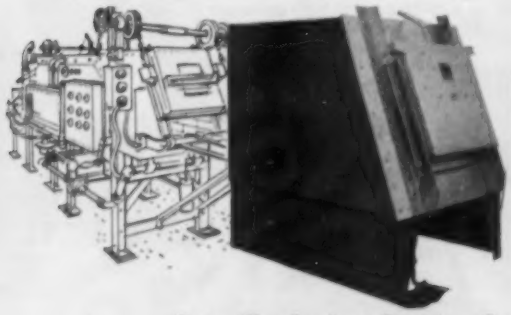

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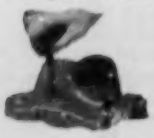

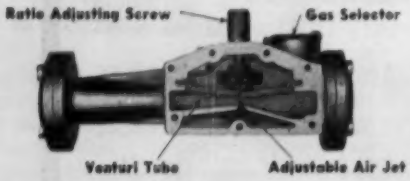

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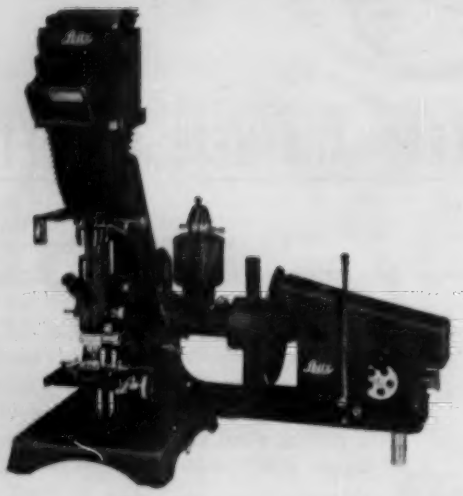

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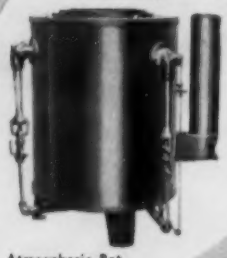

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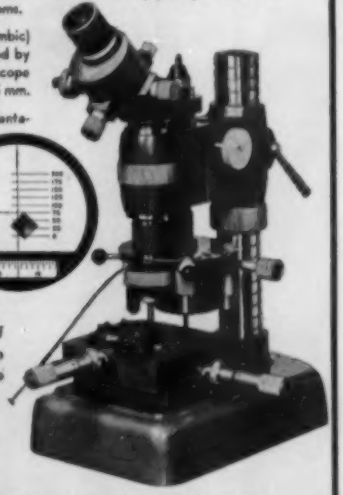

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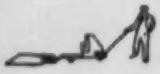

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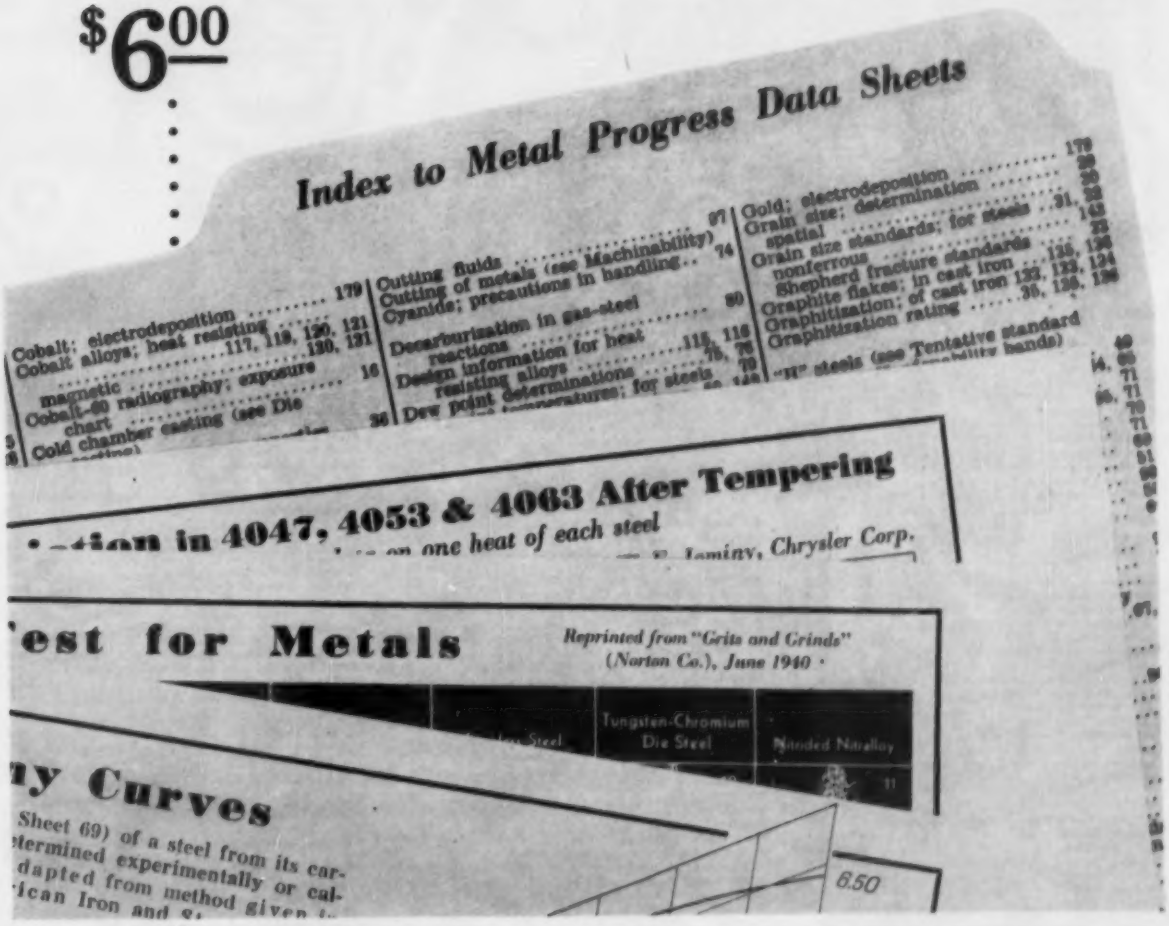
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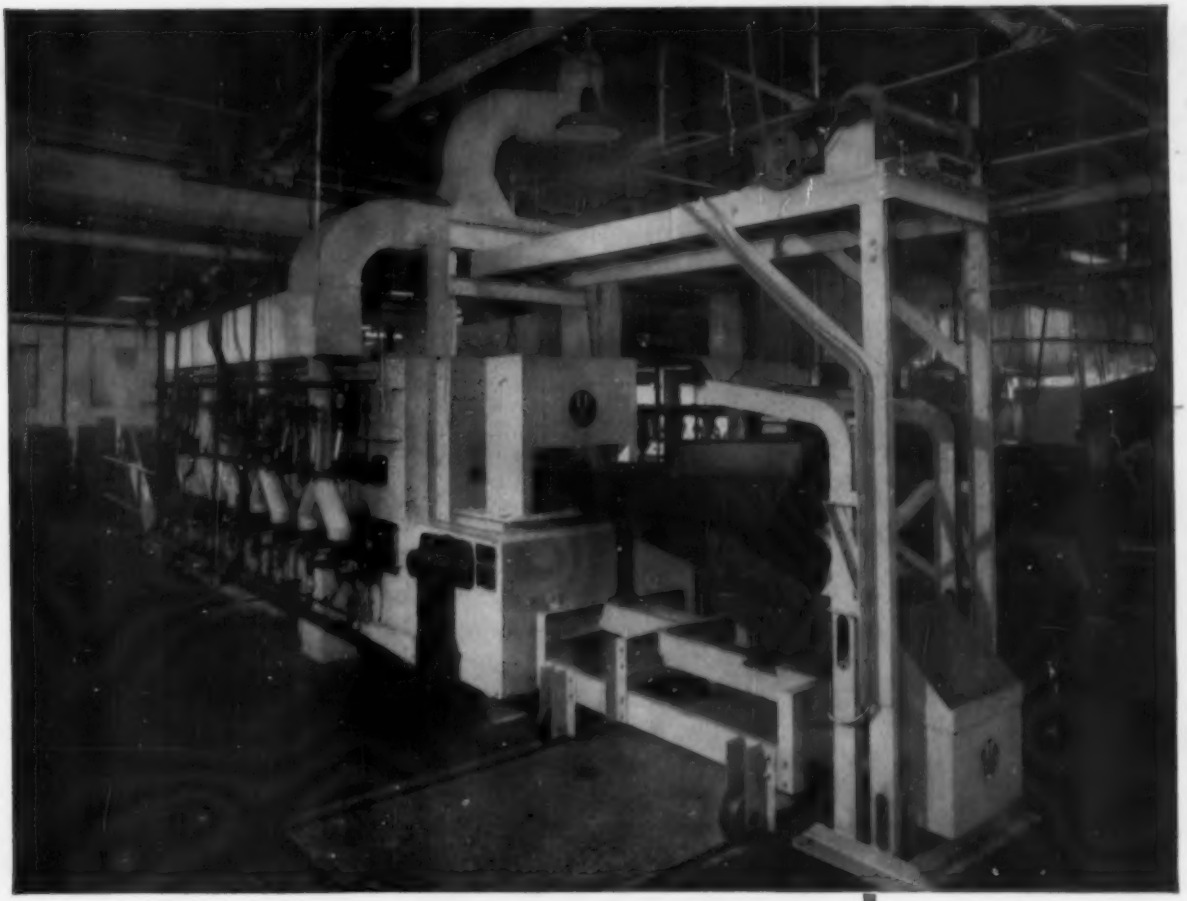

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Ask for Bulletin 461-CB.

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